# Converging Art and Science:

# Considering the Conditions in which

# Women and Girls enter STEM Subjects

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## Abstract

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Girls lose interest in STEM (Science, Technology, Engineering, and Math) subjects at an early age because they are seen as "boys' subjects" (Cooper & Heaverlo, 2010). This research examined the conditions in which women and girls enter the field of science, and whether art can play a role in creating access points for women who encounter hurdles due to restrictive gendering practices. Using the comparative case study design and the theoretical frameworks of complexity theory, gender theory, feminist standpoint theory, and institutional ethnography, this research examined two institutions where art and science intersect: the Exploratorium, a museum of science, art, and human perception, and the SETI Institute, an organization that is dedicated to the search for extraterrestrial life. Two women from each institution were interviewed about their careers in the STEM field.

This study identified commonalities in the institutional philosophies of the women's work environments, and analogous coping strategies employed by the women when encountering gender restrictions. Of special interest is how an emphasis on individual research practice over disciplinary labels and gender categories can replace the labels "artist" and "scientist" with the term "researcher." The shared scripts of performing research create a community of practice, a library of actions and implicit rules and behaviours. This research describes how convergence

points of the communities of practice in art and science can disrupt disciplinary distinctions, and by doing so dismantle the gendered dualities associated with each discipline. These convergence points create access points for women to enter the field of science.

Key terms: art education, STEM subjects, gender stereotypes, restrictive gendering practices, complexity theory, gender theory, feminist standpoint theory, institutional ethnography, performativity, communities of practice

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Für Ulla und Floh

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# Chapter 1. Introduction

## 1.1 Introduction

This research examines the conditions in which women and girls enter the field of science, and whether creative activities like art can play a role in creating access points for women who encounter hurdles due to restrictive gendering practices.

Girls lose interest in STEM (Science, Technology, Engineering, and Math) subjects at an early age, and the rate of disengagement increases throughout their academic experience (Cooper & Heaverlo, 2010). STEM fields are seen as lacking femininity, and the perceived mismatch between girls' self-concepts and the stereotypes associated with science as "boys' subjects" cause girls and women to abstain from STEM disciplines (Kessels, 2014, p. 281). However, recent research has suggested that an emphasis on creativity and design may attract girls to the STEM academic and career fields (Cooper & Heaverlo, 2010). This dovetails with the STEM to STEAM (STEM plus Art) movement, which advocates for cross-curricular activities. Examples of such STEAM projects are Andover High School's "Geometry Through the Lens of Art" course which combines the teaching of math with art, or the California College of the Arts's Eco-Tap course, which fuses art and environmental science (*STEM to STEAM Case Studies*, n.d., [website]).

Can gender stereotypes be disrupted by dismantling the division between the disciplines of art and science? To investigate this question this study examined two institutions where art and science intersect: the Exploratorium in San Francisco, a museum of science, art, and human perception, and the SETI (Search for Extraterrestrial Intelligence) Institute, an organization that is dedicated to the search for extraterrestrial life. Using comparative case study design, this

research explored both institutions' philosophies and institutional practices by conducting interviews, documenting the work environment using photo and video recordings, and by reviewing literature by and about each institution. The main focus of this study are four women who were interviewed about their experiences entering and working in the field of science, and how they integrate art into their work and personal lives.

The women's narratives revealed shared experiences relating to gendering practices in the field of science, and provided insights into the varying strategies the women employed in negotiating restrictive gender norms. The interviews also highlighted the philosophies and institutional practices which created conditions that fostered the women's careers at the Exploratorium and the SETI Institute.

**1.2 Purpose**

The purpose of this research is to investigate the engagement of girls and women with scientific inquiry, and how the integration of science and art can offer new opportunities for women and girls to connect to STEM (Science, Technology, Engineering, and Math) education.

This research combines complexity theory, gender theory, feminist standpoint theory, and elements of institutional ethnography to examine the conditions in which the women of this study entered the field of science and science-informed art. This study investigates overlapping activities which emerged in the women's fields of research, areas where the practices of art and science converged. This study examines these convergence points, and discusses how they may create access points for women to the field of science.

**1.3 Research Questions and Objectives**

This research investigates the institutional conditions which facilitate the work of women in STEM fields, and how the women personally engage with science and art. Specifically, this study addresses the questions:

- What strategies did the women in this study employ to overcome gender-related challenges?
- How are the women supported in their work environment?
- Are there any overlaps between the fields of art and science which could serve as access points for women and girls interested in entering the field of science?

**1.4 Justification and Rationale**

My interest in the intersection of art and science is informed by my work as an artist, gallery owner, and art/science researcher at the SETI Institute. My artwork is influenced by my activities in amateur astronomy, which inspire and inform my research-creation projects. Through my engagement in amateur astronomy I have become aware of the underrepresentation of women in science-related fields, inspiring my investigation into women's engagement with science. I had first-hand experience of the underrepresentation of women in STEM fields when I served as the first female president of the RASC Montreal Centre (Royal Astronomical Society of Canada) in 60 years, and during my tenure as Director of Exhibitions of the IAAA (International Association of Astronomical Artists, www.iaaa.org), where only about 20% of the membership is female.

My research activities in art and astronomy align with my work as owner and director of Visual Voice Gallery, a contemporary art gallery which exhibits art with connections to science. The gallery also offers art-science themed workshops and seminars which complement the gallery's programming. My experiences within the art and astronomy communities, and my interest in educational outreach are my motivation for conducting this research.

This investigation of how the integration of science and art can offer new opportunities for girls to connect to STEM has the potential to help develop theories related to the engagement of girls and women with STEM subjects, and further existing theories of cross-curricular education. If women are excluded from the STEM field, their perspectives and voices will be absent as new technologies are developed (Lee, 2016). Attracting and retaining more women in the STEM workforce will maximize innovation, creativity, and competitiveness, and will create a more resilient and culturally rich society. With a diverse workforce that includes women, technological products and services are likely to be better designed and more likely to represent all users. (AAUW, 2010, p. 3.)

### 1.5 Organization

Chapter two of this thesis begins with a literature review which examines the questions of gender and identity through the lenses of gender theory, feminist standpoint theory, institutional ethnography, and complexity theory. Chapter three outlines case study methodology, defines the selection of the cases, and describes the method of data collection and analysis. Chapter four describes the findings revealed in this case study. Chapter five sums up the research with a conclusion and provides suggestions for future research in STEAM education.

### 1.6 Terminology

*Complexity theory:* the study of large networks "with no central control and simple rules of operation [which] give rise to complex collective behaviour, sophisticated information processing, and adaptation via learning and evolution" (Mitchell, 2009, p. 13).

*Community of practice:* a library of shared scripts, actions, and implicit rules and behaviours which define the roles of practitioners in a particular area of research. The use of the term in this study is distinct from the definition used by Jean Lave and Étienne Wenger in their research into communities of practice, in that it does not include the social, interactive aspect of a community, but focuses on the signifying practices in a specific domain.

*Feminist standpoint theory:* "the philosophic viewpoint that what one knows is affected by the standpoint (or position) one has in society" (Appelrouth and Edels, 2012, p. 574).

*Institutional ethnography:* "a method of elucidating and examining the relationship between everyday activities and experiences and larger institutional imperatives" (Appelrouth and Edels, 2012, p. 563).

*Performativity:* a performative event which is ongoing and culturally sustained (Butler, 1990).

# Chapter 2: Literature Review and Theoretical Framework

## 2.1 Introduction

Central to my investigation are two major questions: how do women and girls engage with scientific inquiry, and how may the integration of science and art help disrupt restricting gender stereotypes? My theoretical framework examines how women's lives are affected by the dualities imposed through gender roles, how fields of knowledge, notably science, become associated with a specific gender, and what strategies art may offer to create access to the field of natural science.

The central focus of this chapter is the idea of 'boundaries,' and how they shape our identities, our gender roles, our interactions at work, and our understanding of our world. In the following pages I will discuss how the acknowledgment, questioning and redrawing of boundaries can especially benefit women. I will focus on feminist theory, specifically gender studies and feminist standpoint theory, but the leitmotif of "boundaries" will also draw on complexity theory, institutional ethnography, and writings about science-informed art.

## 2.2 The Construction of Identity and Gender

### 2.2.1 Identity is an Emergent Construct

How do we know who we are? How do we know that we are different from others, and how do we maintain a sense of self over time? Our unique, personal point of view creates a sense of self that feels immutable, as though we had a core identity. We develop a sense of self by drawing on autobiographical memories, which create a consistent feeling of self-knowledge

(Fivush, 2011). We also have a visceral experience of ourselves, based on what we sound, look, and feel like, which creates a sense of the self as a physical, material object (Oyserman, 2012). The experience of the self as a physical organism, combined with all aspects of psychological functioning and social attributes is what is commonly referred to as the 'self' (Ewing, 1990).

This visceral experience of the self as a core substance is echoed in the theories of classical Greek philosophers like Plato and Aristotle. Their metaphysical worldview was based on the idea that we live in a static universe, and that everything in nature, including ourselves, is defined by its own unique, intrinsic, and immutable substance. For Plato, the physical universe was a distorted reflection of the perfect realm of Universal Forms. Brent Davis (2004) explains: "Within Plato's theory of Ideas, physical objects are seen as reflections or flawed copies of perfect, timeless forms that exist in an Ideal (or Platonic) realm" (p. 17). The Platonic Ideals possessed immutable, permanent core attributes. Aristotle built on Plato's theory and developed the notions of substance, or "essence." Juarrero (2002) elaborates "A substance ... is a nucleus of qualities that jointly embody the nature of the thing in question; a nucleus, moreover, capable of independent existence" (p. 95). Aristotle distinguished between the internal, essential state of a substance and its external, accidental traits. This dichotomy results in a teleological attitude toward change for all living things: any development of an organism's essential state is seen as a purposeful effort to achieve its Ideal form, a refinement of its core essence. Any accidental, superficial changes of the organism's attributes were thought of as corruptions caused by outside influences, which moved the organism away from its Ideal form (Davis, 2010, Juarrero, 2012). In this metaphysical worldview, an organism needed to shield itself from its environment in an effort to protect itself from contaminating its core essence.

Notions regarding autonomy and the nature of change were fundamentally challenged by Darwin's paradigm shifting Theory of Evolution. Says Davis: (2004) "Darwin did nothing less than strip species of the permanence and perfection" (p. 19). Darwin revealed the interdependence between a species and its context. Not only did the mechanics of natural selection connect the dots of individual species on a continuum and thereby blur the hard edges of the Platonic Ideals, it also revealed the inextricable connection between the individual and the pressure of its environment. In Darwinian terms, perfection is the complete harmony between an organism and its environment. If the environment changes, so does the balance, and the organism with the best "fit" survives. Therefore, perfection is not a static state, but a constant flow of adaptation. This new understanding of the interplay between the living form and its environment also fundamentally recast the definition of change. An organism no longer thrives toward a teleologically determined ideal state. Rather, the Theory of Evolution suggests an emergent system, where an organism's development responds to immediate environmental pressures. Any adaptation of the organism is a bottom-up response to its changing context. Evolution simply strives toward equilibrium, and the only thing that is constant is change itself.

Darwin's paradigm shift is echoed in contemporary theories regarding identity and the self in anthropology and psychology. Oyserman, Elmore, and Smith (2012) observe that "Self and identity theories converge in grounding self and identity in social context" (p. 76). The authors posit that self and identity are social products which are based on at least three dynamic motivators: the values and priorities outlined within a social hierarchy, the endorsement of actors within this social hierarchy, and the implications of the immediate situation. According to the authors, endorsement is a particularly important factor, as it reinforces one's sense of value. As a

result, people respond to their cultural and social environments by structuring their self-concepts to harmonize with others' expectations of them. "People may organize and structure their self-concepts around some domains that others commonly use to make sense of them - their race or ethnicity, their gender, their weight, their age, their academic standing in school." (Oyserman et al, 2012, p. 73). In effect, an identity is constructed to create the best possible "fit" with its social environment, echoing Darwin's Theory of Evolution.

Not only is identity meshed with the expectations of our social context, it is also in constant flux. Oyserman et al. (2012) observe that "identities are not the fixed markers people assume them to be but are instead dynamically constructed in the moment" (p. 70). This notion is supported by Ewing (1990), who notes that "people construct a series of self-representations that are based on selected cultural concepts of person and selected "chains" of personal memories. Each self-concept is experienced as whole and continuous, with its own history and memories that emerge in a specific context, to be replaced by another self-representation when the context changes" (p. 253). This means that in the temporal flow of experience, there is a recursive and ongoing reconstruction of our selves. The self is simultaneously a product of its social context and a shaper of behaviour in its social context. Our very identities are recursive, emergent systems.

Juarrero (2002) builds on the concept of recursiveness and emergence by describing identity as a complex dynamic system, and by moving the idea of the self from a central core essence to a surface boundary. Complex dynamic system (CDS) is a term used to describe "large networks of components with no central control and simple rules of operations that give rise to complex collective behaviour, sophisticated information processing, and adaptation via learning

and evolution" (Mitchell, 2009, p. 13). These networks are self-organized, bottom-up emergent, and are in continual flux (Davis and Sumara, 2006). A key component of a CDS is its dynamic integrity, its resilience within this constant environmental flux. Juarrero (2002) defines robust resilience as the "ability to absorb environmental perturbations and evolve into a metastable level of organization" (p. 99). The author notes that the more connected a system is to its environment, the more robust and resilient it will be. The system is not only constructed by its environment, it is also dependent on its connections to the environment to be able to flourish. This intimate meshing of system and context raises the question of how the system itself is delineated. Davis and Sumara (2006) list as one of the defining attributes of a CDS that it is "ambiguously bounded," meaning that judgments about a system's edges "may require arbitrary impositions" (p. 5). It is these system edges which are of interest to Juarrero. The author likens them to boundaries, following Cilliers's (2002) definition of boundaries and limits: "A boundary is something with two sides, like the boundary of a country. A limit, on the other hand, we can only know from one side, that is, we cannot know what is beyond it" (p. 82).

Juarrero identifies boundaries as active sites which are permeable, sites of "phase change." Boundaries possess properties similar to membranes, "which both exclude some potential inputs (thereby maintaining system integrity) at the same time as they include others (thereby allowing for the possibility of dynamic transformation)—are thus ultimately responsible for both a system's actual identity as well as its potential and actual evolution" (Juarrero, 2002, p. 100). Existential decisions are made at this boundary between the individual and its context. The degree of permeability of the boundary is one of the defining characteristics of the individual, balancing resistance to change with openness to change, integrity with flexibility. In this

balancing act the self is being continually constructed in a feedback loop with its cultural environment. Thus, the self is in a constant dynamic flow of evolution, and each phase change is both a recursive and emergent act. Boundaries define us, but they don't confine us.

### 2.2.2 Gender Is an Emergent, Cultural Construct

If identity is an emergent construct, what about gender? Are sex and gender intrinsic to the self or are they, too, constructed by cultural pressures? Conservative gender roles and recurrent tropes in popular culture (notably Gray, 1992) suggest that "Men are from Mars, Women are from Venus." This attitude suggests that men and women are intrinsically different, and that these core differences are the cause of the divergent behaviours and abilities of the sexes. However, this Platonian Ideal of sex and gender is being challenged by feminists and gender researchers.

In her book "Gender Trouble" (1990) feminist author Judith Butler argues that both sex and gender are culturally constructed. Butler posits that gender is not inherent in us, but that it is continually acted out by us. Says Butler "Gender is a kind of persistent impersonation that passes as real" (p. 5). This continual acting out of gender recursively produces gender, an act which Butler terms as "performative." Butler distinguishes between performance, as a distinct, completed event executed by a performer, and "performativity," which is ongoing and culturally sustained (Appelrouth and Edels, 2012). According to Butler, we become subjects from our performances. Our identities are generated by rules that continually condition our behaviour, which means that identity is a "signifying practice" (1993, p. 145) that operates through repetition. Butler believes that "what we take to be an internal essence of gender is manufactured

through a sustained set of acts. ... what we take to be an "internal" feature of ourselves is one that we anticipate and produce through certain bodily acts" (p. 9, 1999).

Butler differs from second-wave feminists, who distinguish between sex, as the biological predisposition of the body, and gender, which are the cultural norms which form identity. Butler suggests that since the societal pressures that create gender 'sex' the body, the act of splitting sex from gender could result in a "radical discontinuity." On the one hand, if gender simply mirrors sex, it would refute the notion that gender is culturally constructed. On the other hand, if sex and gender are independent from each other, gender would become a "free-floating artifice." Instead, Butler suggests that "being" a gender is an effect of cultural discourse, and she understands the body as a prediscursive, neutral ground onto which gender acts. However, the body is not a passive "surface awaiting signification," but as a "set of boundaries, individual and social, politically signified and maintained" (p. 33).

Note here the parallels between Juarrero's description of identity as an actively evolving, recursive system defined by boundaries, and Butler's notion of sex and gender as "a set of boundaries." Butler also points to the restrictions that police these boundaries in gender politics. If gender is culturally constructed, it does so within culturally enforced power relations. The cultural norms which shape sex and gender play an essential part in the power dynamics of gender. Identifying as one (woman) necessitates the other (man), and so shapes a symmetrical gender binary system based on stable opposites. Any action that disturbs this balanced duality is identified as problematic and is punished and excluded, such as gay, lesbian, transgender, and intersex individuals.

Butler suggests that both sex and gender are purely a function of societal regulation, and that the body is a recipient of culture. This idea is echoed in the research of biologist and gender researcher Anne Fausto-Sterling, who investigates gender issues and the effects of cultural pressures on the body. Fausto-Sterling suggests that sex is fluid on the biological level and that "the boundaries separating masculine and feminine seem harder than ever to define" (2000, p. 19). Fausto-Sterling (2000) distinguishes between sex at the genetic and cellular level, at the hormonal level, and at the anatomical level. At any point during human development, both pre- and post-natal, the development of biological sex can be disrupted or altered. For example, genetic markers may be inconsistent with anatomical standards of gender, or hormonal developments may alter sexual developments during puberty. Fausto-Sterling understands biological sex not as a Platonic Ideal, but rather as a statistical function. "Male and female, masculine and feminine cannot be parsed as some kind of continuum. Rather, sex and gender are best conceptualized as points in a multidimensional space" (2000, p. 22).

Not only do biological factors contribute to the fluidity of sex and gender, but societal gender roles can directly impact biology. Says Fausto-Sterling "Our bodies physically imbibe culture" (2005, p. 1495). Fausto-Sterling sees the body as a dynamic system, and her research focuses on process-oriented accounts of the body. This is especially evident in her study "Sexing the Baby" (2011) which examines early-appearing sex-related behavioural differences of children in the first three years of their lives. The study revealed that gender roles are imposed very early on as children are enculturated, which then lead to significant differences in gender-specific ability. For example, the fact that girls perform better than boys in language production can be traced back to the fact that parents vocalize more with baby girls than with baby boys. As

a result, baby girls' speech development accelerates faster. The increased exposure of language has a direct effect on the strength of connections of cells in the brain and re-enforces the language centres of the brain. Small differences in behaviour at a young age become more significant and pronounced as children age. The study demonstrates that gender roles can change the body on a biological level by altering structures in our nervous system and our brain, supporting the claim that the body itself is plastic and responds to cultural stimuli. As a result, Fausto-Sterling understands sex and gender as "a constant co-production of body and culture" (2009, 24'11").

Juarrero, Butler, and Fausto-Sterling demonstrate that our identities, our sense of personhood, and our gender identification are not preordained fixtures, but fluid, emergent systems, defined by boundaries which are continually negotiated in a cultural context. This context is not value-neutral, but as Butler noted earlier, if gender is culturally constructed, it does so within culturally enforced power relations.

## 2.3 Society Imposes Gender Roles which Limit and Restrict Women

### 2.3.1 Performing Gender in the Workplace

Culturally enforced power relations not only construct the individual, they also shape the identity and gendering practices of workplaces. How does job-related gendering in institutions shape the behaviours of men and women?

Institutional ethnographer and feminist Patricia Yancey Martin dovetails with Butler's theory, in that both see gender as a social institution that is established and sustained through recursive performative acts. Yancey Martin (2003) notes that women and men routinely practice

gender “in embodied interactions that are emergent and fluid, grounded in practical knowledge and skills, and informed by liminal awareness and reflexivity” (p. 342). The author distinguishes between gendering practices and practising gender. “Gendering practices” are a class of activities that are available for people to enact in an encounter in accord with the gender institution. It is a set of norms, a library of potential actions which outlines a configuration of practice. Gendering practices are based on tacit knowledge that is acquired over time and deployed through repetition. They are recursive scripts that both inscribe past performances and prescribe future performances. These practices are learned and enacted in childhood, it is, for example, how one learns how to “act like a girl” (p. 351). “Practising gender” refers to an actual event where the gendering practices are performed. These micro-interactional performances are executed un-reflexively, spontaneously, and take place on a liminal level. Those skilled at practising gender do so almost effortlessly, as though it was their second nature.

Yancey Martin observes that the two-sided dynamic of practising gender within the norms of gendering practices results in a recursive practice where men and women continually construct each other at work. While this practice significantly affects both women’s and men’s work experiences, the author’s studies reveal that gendering practices negatively impact women workers’ identities and confidence. “The gender institution holds women accountable to pleasing men; it tells men/boys they have a (gender) right to be assisted by women/girls” (p. 346). The author argues that gendered practices from other realms such as the home and family structures, where women are placed in a “helper position” come to bear in the work environment. However, if a woman attempts to alter the gender practice, for example by occupying a leadership position instead of a helper position, she risks being seen a “rocking the boat” (p. 347) which may lead to

detrimental consequences. While gender practices are prescriptive for both men and women, the organizational gender institution is unbalanced. Yancey Martin's studies demonstrate that gender-constructed power dynamics bolster men's claim that they, in fact, don't perform gender. Since in the masculinist power structure "human" is equivalent to "man," men can simply claim neutrality. However, women are always seen as practising gender by men. As Yancey Martin points out, women are seen as "the other," and don't enjoy the privilege of disembodied invisibility.

This imbalance between the dominant, normative (male) group and the subordinate, "other" (female) group is the object of study of institutional ethnographer and feminist Dorothy Smith. Women navigate the institutional gender imbalance by employing what Smith (1987) terms a "bifurcation of consciousness": a separation or split between the world as they actually experience it and the dominant, masculine view to which they must adapt. Appelrouth and Edels (2012) elaborate that "as the subordinate group, women are conditioned to view the world from the perspective of the dominant, male group, since the perspective of the latter is embedded in the institutions and practices of that world, while the dominant group, on the other hand, enjoys the privilege of remaining oblivious to the worldview of the Other, or subordinate group, since the Other is fully expected to accommodate to them" (p. 562). The mechanism of bifurcation is supported by the observations by Oyserman et al. (2012) mentioned earlier, which highlighted that people respond to their cultural and social environments by structuring their self-concepts to harmonize with others' expectations of them. The context established by the dominant group combined with the compulsion to cohere with social expectations means that women often occupy two worlds.

### 2.3.2 The Role of Gender Within the Field of Science

If gender differences are apparent in institutional organizations, they are especially pronounced in the field of science. Feminist authors Donna Haraway and Sandra Harding argue that scientific objectivity is constructed by and equated with men, and that similar to the construction of personal and institutional identity, science is also socially constructed. How does the dominant, male perspective influence the field of science?

Haraway (1988) questions the "ideological doctrines of disembodied scientific objectivity" (p. 576). Instead, she claims that science is a socially constructed product of discourse. Haraway asserts that "science is rhetoric, a series of efforts to persuade relevant social actors that one's manufactured knowledge is a route to a desired form of very objective power." The author argues that knowledge claims are made by privileged insiders, and that their persuasive discourse is equivalent to power moves. Not only is knowledge power, knowledge is also constructed by power. However, if the nature of truth is rhetorical, it follows that science is contestable. Therefore, a change in power structure may fundamentally disrupt the nature of science.

Harding places science in its historical and political context. Harding (1995) notes that whereas the birth of science at the time of the Enlightenment may have created a democratic, rebellious counterpoint to feudalism and religious superstition, today's science acts like a conservative monopoly. The control of resources for research and publications, military and commercial secrecy, and the barriers of technical jargon limit the access of science to the general public. Contemporary science has become institutionalized, and its "normalized politics of male

supremacy, class exploitation, racism, and Eurocentrism, shape our images of the natural and social worlds" (p. 343). In other words, science is not value neutral, but is shaped by politics: the political agendas of special interest groups, and the institutional, hierarchical politics of research institutions. As argued earlier by Smith, the perspective of the dominant, male group is embedded in institutional practices, and this mechanic comes to bear in institutionalized science. However, this masculinist bias is unacknowledged, because, as noted by Yancey Martin, privilege is transparent to those in power, allowing men to claim neutrality. This "disembodiment" of the male dovetails with Haraway's notion of "disembodied scientific objectivity," a fundamental aspect of scientific objectivity.

Haraway questions the notion of objectivity. She asserts that science is "about a search for translation, convertibility, the mobility of meanings, and universality" (1988, p. 580). According to Haraway, this universality implies the fantasy of an ultimate truth which promises transcendence, omnipotence, and immortality. Note here that she is draws back on the Platonist worldview of science, a worldview that is based on the idea that there is a truth "out there," waiting to be discovered, a universe of Platonic Ideals independent of the truth seeker. This universality is reflected in the disembodied vision of scientific research. Haraway employs a vision metaphor to illustrate the masculinist, objective standpoint when she equates science, and especially technology, with a disembodied eye: it has no position, it is everywhere at once. From the glimpse of the infinitesimally small provided by a microscope to the astronomical visions transmitted by telescopes, the singular, technological eye affords the "conquering gaze from nowhere" (p. 581). It is what Haraway refers to as the "God trick:" an omnipotent perspective,

divorced from the researcher, “the standpoint of the master, the Man, the One God, whose Eye produces, appropriates, and orders all difference” (p. 587).

As an antithesis to the God trick, Haraway proposes a feminist reimagining of objectivity. Her version of feminist objectivity is about limited location and situated knowledge, not about transcendence and the splitting of the researcher from the research. Haraway proposes a paradox: only partial perspective promises objective vision. Feminist objectivity grounds knowledge by situating the researcher, and by extension the researcher’s context. “Situated knowledges require that the object of knowledge be pictured as an actor and agent” (p. 592). Here Haraway transforms science from an act of persuasion, where the dominant group imposes its vision, to “power-charged social relation of ‘conversation’ “ (p. 593).

Harding agrees, arguing that what we do in our social relations both enables and limits what we can know. “All human thought can necessarily only be partial. The dimension of our social location enables and limits our thoughts” (1995, p. 346). Harding posits that to gain a critical view, one must step outside one’s conceptual schemes. While it is impossible to be in anyone else’s shoes, it is possible to enlarge one’s view through dialogue with those who hold different positions in the power structure. Harding agrees with Dorothy Smith that the standpoint of women “enables us to understand women’s lives, men’s lives, and the relationship between the two” (p. 347). Both Haraway and Harding foreground the researcher, acknowledge subjectivity, and convert science from a monologue to a dialogue. Science is still discursive, but the conversation now becomes a boundary, an active site where the experiences of both men and women are a resource.

## 2.4 Recognizing that Gender and Identity are Cultural Constructs Means that they can be Changed

### 2.4.1 Using Gender Analysis as a Resource

Adding the insights and perspectives of women enables a richer dialogue in the field of science. Acknowledging gender practices and taking a grounded, subjective standpoint can reveal biases and barriers that have previously been overlooked. How can gender studies be deployed to lead to innovation in science?

Echoing the theories of Haraway and Harding, gender and science scholar Londa Schiebinger acknowledges that with respect to gender, science is not value-neutral. Schiebinger asserts that "Gender bias in research limits scientific creativity, excellence, and benefits to society" (2011, p. 157). Schiebinger notes that identifying gender practices should only be a first step. After identifying gender dimensions in institutional practice, insights gained through gender analysis can be used as a resource to construct more complete knowledge "by offering new perspectives, posing new questions, and opening new areas of research" (p. 155).

Schiebinger promotes the concept of "gendered innovations," which she defines as "the process that integrates sex and gender analysis into all phases of basic and applied research to assure excellence and quality in outcomes" (p. 154). To illustrate her point, Schiebinger provides a case study that highlights a flaw in seatbelt design. The author cites a 2001 study by Weiss, Songer, and Fabio which states that in the U.S., 82% of fetal deaths with known causes result from motor vehicle collisions, and that the fetal deaths are correlated with the fact that conventional seatbelts do not fit pregnant women properly. As Schiebinger notes,

"In much engineering design, men are taken as the norm; women are analyzed as an afterthought and often studied from the perspective of how they deviate from the norm. This means that women may be left out of the 'discovery' phase - as a result, many devices are adapted to women retrospectively, if at all." (p. 160). A pregnant version of the crash test dummy wasn't invented until 1996, and it was only in 2002 that Volvo's mechanical engineer Laura Thackray designed the world's first computer generated pregnant crash-test dummy. However, the current three-point seatbelt is already so firmly established, that new seatbelt designs are not being implemented. Had gender analysis been part of the design process from the beginning, seatbelt design would have included safety features that better serves both men and women. Schiebinger concurs with the WHO, stating that "It is not enough simply to 'add in' a gender component late in a given project's development. Research must consider gender from the beginning" (p. 158).

### 2.4.2 Disrupting the Boundaries of Gender

Including the perspectives of women in the dialogue of science broadens the boundaries of scientific research and can lead to innovations which benefit both genders. As we have seen earlier, gender dynamics tend to exclude women by "othering" them, and by relegating them to a subordinate status. How, then, can the boundary between the genders be disrupted to include the perspective of women?

Judith Butler disrupts the gender divide by arguing that the category "women" does not exist. As discussed earlier, the basis of Butler's gender theory is the notion that gender is socially constructed, and that the set of boundaries which delineates gender is policed by the dominant,

male social group. The masculinist power structure is reflected in discursive practice, which created the category "women" to separate the feminine from "the constitution of class, race, ethnicity, and other axes of power relations" (1990, p. 4). By denying the validity of the category "woman," and by asserting that both sex and gender are performative, social constructs, Butler makes it possible for the boundaries of gender to be made more permeable. She suggests to "make gender trouble" (p. 34) by disrupting the discursive script that prescribes the performity of gender. Butler notes that the signifying practice of identity operates through repetition. It is by disrupting this repetition that gender boundaries can be transformed from regulatory limits to dynamic sites. Modulating repetition restores agency to the individual, and Butler argues that " 'agency,' then, is to be located within the possibility of a variation of that repetition" (p. 145). Rather than performing gender "like a woman" or "like a man," Butler incites gender trouble: "The task is not whether to repeat, but how to repeat or, indeed, to repeat and, through a radical proliferation of gender, to displace the very gender norms that enable the repetition itself" (p. 148).

Sandra Harding mediates the power dynamic of gender politics by including the standpoint of women in knowledge production. Harding is critical of the notion of objectivity as it is deployed in the field of institutionalized science. As outlined previously, Harding critiques contemporary science by equating it with a conservative monopoly which acts to serve a masculinist political agenda. Harding (1995, 1997) notes that objectivism defends and legitimates scientific institutions and practices by certifying them as value-neutral. However, Harding questions claims of neutral objectivity, arguing that both the politics of scientific institutions and the cultural context of the individual researcher influence knowledge production.

Furthermore, the ostensible "value-neutral" objectivity, which Harding terms "weak objectivity," demands the "separation of thinking from feeling" and the promotion of "moral detachment" (1995, p. 341). Instead, Harding proposed a "strong objectivity," which extends the notion of scientific research to include the systematic examination of background beliefs to include previously unacknowledged cultural agendas (1997, p. 149). Since cultural agendas in a gender-stratified society discriminate against women, Harding argues that the women's standpoint affords valuable insights because an oppressed group is less interested in ignorance about the social order and is less invested in maintaining or justifying the status quo than does the dominant group. Harding (1991) stated that "Using women's lives as grounds to criticize the dominant knowledge claims, which have been based primarily in the lives of men in the dominant races, classes, and cultures, can decrease the partialities and distortions in the pictures of nature and social life provided but the natural and social sciences" ( p. 121). Accounts of the distinctive features of women's lives become a resource for richer, more complete knowledge production, echoing the recommendations of Londa Schiebinger who advocates for the inclusion of gender analysis as a fundamental part of research. The boundaries of scientific objectivity are being redrawn to acknowledge and include subjective standpoints of both men and women.

Donna Haraway suggested that identity and gender boundaries can be modified by disrupting dualities. Her Cyborg Manifesto (2000) served as a metaphor for the act of fusing and confusing established taxonomies. Haraway defined a cyborg as a hybrid entity that dismantles dualities by extending its identity past its boundaries. Cyborgs are not autonomous individuals, but a collective of organisms: "The cyborg is a kind of disassembled and reassembled, postmodern collective and personal self" (p. 302). This blurring of boundaries is made possible

by emergent changes in contemporary society regarding the nature of class, race, and gender, as well as by advances in science which contribute to the breakdown of the boundary between the physical and non-physical world through miniaturization of technologies, biotechnology and computer programming. Haraway posits that we are transitioning from "an organic, industrial society to a polymorphous, information system" steered by advances in communications technology, where microelectronics and computers enable and control society. Haraway's worldview echoes that of Juarrero, in that she also rejects Platonic materialism and Aristotelean ideas of essence, and places the idea of identity at the boundary: "We are responsible for boundaries, we are they" (p. 315). Haraway argues that the world is changing from an object-based epistemology, which is grounded on essential properties, to a design-based epistemology, which functions through the negotiation of boundary constraints. In this system, control is exerted on boundary conditions and not on the integrity of objects. The boundary has the power to dissolve, or "disperse dichotomies such as mind/body, animal/human, organism/machine, public/private, nature/culture, men/women, primitive/civilized" (p. 313). As a result, our bodies don't end at our skins but extend across taxonomic categories.

As dualities are dispersed, so are gender norms. Haraway states that "the cyborg is a creature in a non-gendered world" (p. 292). In fact, Haraway agrees with Butler that there is no "female category" when she states that "there is nothing about being 'female' that naturally binds us as women." Haraway suggests that by re-ordering the body boundary we can reorder society. Therefore, "gender might not be a global identity after all, even if it has profound historical breadth and depth" (p. 315). Haraway's cyborg metaphor dismantles the homogenous definition

of woman as defined by society by allowing women to delineate their own boundaries of gender identity.

## 2.5 Boundaries Between Art and Science Have Become Permeable

The strategies outlined by Butler, Harding, and Haraway to transgress gender boundaries and disturb power relations are based on tactics of discourse. While changes in language may influence public attitudes, is subversive speech a sufficiently powerful tool to deploy social justice? Martha Nussbaum (2000) does not think so. She critiques second-wave feminists,' and specifically Butler's, approach of solely focusing on language: "Feminist thinkers of the new symbolic type would appear to believe that the way to do feminist politics is to use words in a subversive way, in academic publications or lofty obscurity and disdainful abstractness. These symbolic gestures, it is believed, are themselves a form of political resistance" (p. 66). Furthermore, Nussbaum reproaches Butler's lack of scope: "In Butler, resistance is always imagined as personal, more or less private, involving no unironic, organized public action for legal or institutional change" (p. 74). How, then, can the strategies of boundary transgression be deployed outside academia and on a larger scale?

### 2.5.1 Disrupting the Boundaries of Fields of Knowledge

Enlarging the scope from discourse strategies limited to the humanities to transdisciplinary knowledge building may be an effective way to deploy feminist strategies of boundary transgression. As noted earlier, power relations of gender are especially pronounced in the field of science. Science, and scientific objectivity, are associated with industrial power and

masculinism. This male bias toward science is already evident in schools: a poll conducted in 2009 by the American Society for Quality of children between the ages of 8 - 17 showed that only 5% of the girls expressed an interest in an engineering career, compared with 24% of the boys. The main cause of the gender gap is girls' perception that science is unfeminine (Lee, 2016, Kessels, 2014) and that girls underestimate their abilities in science (Fink, 2015). Since students are more likely to become engaged in domains that they believe fit their self-concept while abstaining from domains they see as too different from themselves (Kessels, 2014, p. 283), girls gravitate away from the sciences and toward the arts. However, girls tend to do as well as boys in math and science during adolescence (Leaper et al., 2012, p. 269), demonstrating that the cause for girls' shift away from science is rooted in ideas of gender roles, not in ability. Therefore, a blurring of the boundaries between science and art has the potential to also blur the associated gender roles.

### 2.5.2 From Changing the Script to Communities of Practice: Dissolving Boundaries

Both Juarrero and Butler understand identity as an actively evolving, recursive system defined by boundaries. Butler adds the idea of performative scripts, and the notion that we become subjects from our performances. This focus on recursivity and performativity can be applied to redefine the categories of "scientist" and "artist." This ontological stance shifts the definition of the identity of scientist and artist away from the idea of an essence, a core talent which makes someone a scientist or an artist, and defines both through their signifying practice. The identity of the scientist and the artist is informed by their actions, by shared scripts which define their roles. The shared script creates a community of practice, a library of actions and

implicit rules and behaviours which parallels the gendering practices outlined earlier by Yancey-Martin. When viewed from this perspective, the disciplines are more alike than different. As Wilson, Hawkins & Sim (2015) point out, “while there appears to be common acceptance of fundamental differences between art and science, on the one hand, there is also general agreement that the two endeavours share many similarities when viewed as communities of practice” (p. 154). These similarities are found in the parallel cultures of experimentation, as “artists and scientists often more strongly identified with being practitioners directly involved in research than they identified with the specific traditions of their own individual fields of practice” (p. 154). Wilson et al. also note the parallels between art studios and science laboratories as “places of discovery and curiosity,” as well as the important roles of mastery of craft and expert judgement play in both disciplines (p. 154). The term "community of practice" is was coined by anthropologist Jean Lave and educational theorist Etienne Wenger, whose research explores social learning contexts. Lave and Wenger define a community of practice as "a process of collective learning in a shared domain of human endeavour" (Wenger & Trayner, 2015, p. 1). As such, a community of practice is comprised of three key components: a shared domain of interest, a common repertoire of practices, and a community where members interact. Lave and Wenger's work focuses on the social aspects of communities of practice, specifically collective learning, the peer-to-peer sharing of information, the social standing within a group of learners, and learning as the production of identity (Wenger, 2009). However, in this study the use of the term "community of practice" references a shared repertoire of signifying practices in a specific domain, specifically the practice of research and its convergence points in the domains of art and science.

In his book “Colliding Worlds” (2014), historian and philosopher of science Arthur I. Miller examines the emerging trend of art-science by interviewing a series of artists who collaborate with scientists to create artworks which sit at the boundary of art and science. Miller quotes bioartist Marta de Menezes, who states that “We are witnessing the birth of a new form of art: art created in test tubes, using laboratories as art studios" (p. 189). De Menezes is a trained artist and an autodidact scientist. She gained international attention for her work *Nature?* (2000), for which she interceded in butterflies’ pupation process to create new, asymmetrical wing designs. For this project she collaborated with a research team at the University of Leiden, who had first developed this method of intervention. The *Nature?* project connects questions of aesthetics, human intervention in nature, naturalness, and the creative process. While the work is influenced by science and has been created in a lab, de Menezes nevertheless considers it to be a piece of art: “"I always refer to my work as art, not as science-influenced art. It is art in every part of it, and very clearly not science. I'm a science-influenced artist who makes art with a strong scientific content” (p. 210).[2] Collaboration is a recurring theme, and the shared work further blurs the definitions of artist and scientist. "The questions are so deep today that they demand specialization” notes Rolf-Dieter Heuer, the director general of the Conseil Européen pour la Recherche Nucléaire (CERN) and vocal supporter of CERN’s artist-in-residence program Collide@CERN. However, states Heuer, specialization does not lead to isolation: “All is teamwork, to function as a creative group" (p. 166). Miller observes that the labels “artist,” “scientist,” and “engineer” are becoming increasingly irrelevant and are often replaced with the term “researcher” (p. 115). Born & Barry (2011) concur, defining the emerging field of art-science as a pool of shifting practices which “forms part of a larger, heterogeneous space of

overlapping interdisciplinary practices at the intersection of the arts, sciences and technologies" (p. 104).

Artists working in the field of art-science, such as Marta de Menezes, disrupt the performative scripts of "artist" and "scientist" by fusing established communities of practice. By focusing on the acts of researching, observing and experimenting, art-scientists question and redefine the role of the artist and create common ground.

### 2.5.3 Introducing an Interplay Between the Subjective and the Objective

Concurrent with the merging of communities of practice, methods and hierarchies of knowledge production are also being examined. As outlined earlier, both Harding and Haraway question the validity of scientific objectivity and absolute knowledge claims, asserting that all knowledge claims are a product of discourse and power moves. This standpoint is echoed by Born & Barry (2010), who question the authority of science over other fields of knowledge production by proposing that knowledge is socially constructed, and thereby inherently interdisciplinary. This idea of interdisciplinarity opens a space where objectivity and subjectivity may coexist. Harding's call for a "strong objectivity" suggests that scientific research should ground knowledge by situating the researcher through a systematic examination of background beliefs and cultural agendas. Effectively, Harding is (re)embodying the scientist by foregrounding the researcher and by acknowledging his or her subjectivity. This approach runs parallel to the creative practice of the artist. Art is by its very nature subjective and embodied. As Ede (2005) notes, a work of art foregrounds "the values relative to the value-maker, attests to multiple layers of possible meaning, is inevitable only in that it privileges the mores of a

particular culture at a particular time in history" (p. 15). Wilson et al. (2015) add that "art is seen as an aesthetic expression of inter-subjective knowledge, personally created by the artist" (p. 154). Collaborative projects which merge communities of practice, such as art-science collaborations, can be an effective strategy for intertwining subjective standpoints with objective, scientific methods. Harding faults "weak objectivity" for its separation of thinking from feeling and its moral detachment. However, through interdisciplinary, collaborative projects the artist's practice of introspection and reflexivity can connect scientific research to the human condition. Artistic practice can create a space for scientists to acknowledge and reflect on subjective issues and ethical concerns. Art can also act as an "agent provocateur," highlighting areas of concern that may otherwise be overlooked. Ede (2005) notes that "Art has always played an important role in holding a mirror up to nature and it often reflects the debates and conflicts of its period, particularly in our own times by exaggerating, distorting, shocking, teasing and reproving" (p. 71).

However, caution is advised. Andrew Yang (2015) disapproves of the emergent trend of fusing art and science. Yang sees interdisciplinary collaborations between art and science as deeply problematic. The author states that the resulting art-science projects are neither art nor science, but "garbled mistranslations of science" ripe with "questionable aesthetics (and) clichéd tropes" (p. 319). What is needed, according to Yang, is a new epistemic approach, one that focuses on uncertainty. Yang argues that both artistic and scientific practice reconfigure meaning-making and work in a space "where the facts run out," and that "both artistic and scientific practices often seek opportunities to configure new and largely uncharted kinds of meaning" (p. 319). Yang proposes to abolish disciplinary distinctions, to reimagine disciplinary institutions,

and to create a polymorphous practice which focuses on skills: “The artist, scientist, writer, philosopher or activist could be one and the same person—and authentically so—working in great uncertainty to redescribe the world in motion” (p. 20). By foregrounding uncertainty, Yang aims to undermine the hierarchical power structure of knowledge where scientific objectivity outranks artistic subjectivity. While Yang cautions against the superficial exploitation of science tropes in the field of art, he does support interdisciplinary practice if it is grounded in meaningful questioning. This epistemological shift, which focuses both on the researcher as well as the research, allows for the exploration of both subjective and objective viewpoints.

## 2.6 Summary

Our identities are complex dynamic systems, embedded in a social ecosystem that is constantly evolving. We are connected to our environment by a boundary, an active site where existential decisions are made regarding our evolution and identity. Our sense of personhood, our gender identity, and even our bodies are co-constructed by societal cultural norms. These norms are not always equitable. Power relations are expressed through gendering practices which equate men with “normal,” and women with “other,” which results in an imbalance between the dominant, male group, and the subordinate, female group. This effective thickening of the boundary between men and women establishes absolute dualities. In a parallel power move, in the field of science objectivity is constructed by and equated with men, rendering women invisible. Feminist standpoint theorists argue that women’s voices can be made audible by acknowledging gender bias, and by situating the researcher in his or her cultural context. By

doing so, gender analysis can become a valuable resource for innovative practices in science and technology which may benefit both genders.

Feminist writers and gender theorists point toward strategies which exploit the fact that we are continuously constructing our identities by performing culturally prescribed, recursive scripts. By disrupting these scripts, restrictive, hardened boundaries can be reactivated and made permeable. In the field of science, remodulating performativity and acknowledging subjectivity may help to disperse gender norms. Both subjectivity and performative practice are integral aspects in the field of art. By focusing on communities of practice and the signifying practice of research, the boundary between art and science can be permeated, creating an inclusive, transdisciplinary space that is accessible to both men and women.

This thesis approaches the interactions of the women in this study with their educational and work environments as complex dynamic systems. This means that the signifying practices which create the women's identities are understood as recursive, continually constructed boundaries. These boundaries are active sites, where perpetual negotiations take place between the drives and career goals of the women, and the culturally constructed environment which imposes restrictive gender norms. Complexity theory and feminist theory merge in proposing that these gender norms can be collapsed by focusing on signifying practices which modulate dynamic boundaries rather than on restrictive categories and labels which impose static limits.

# Chapter 3. Methodology

## 3.1 Introduction

This research investigated how women navigate the restrictions imposed by gendering practices, and how a blurring of the boundaries between art and science may disrupt prohibitive gender norms. To this end, this study interviewed women who work at the intersection of art and science, and explored the philosophical frameworks and attitudes of the institutions where they work. Using the comparative case study design, this research interviewed two women who work at the Exploratorium in San Francisco, a museum of science, art, and human perception, and two women who work at the SETI (Search for Extraterrestrial Intelligence) Institute, an organization that is dedicated to the search for extraterrestrial life.

## 3.2 Case Study Methodology

Yin (2009) defined case study methodology as an “empirical inquiry that investigates contemporary phenomena in depth and within its real-life context" (p. 18), and noted that case studies are the preferred method when “how” or “why” questions are being posed. Case studies examine contemporary events, usually through interviews and direct observation. In a comparative case study design, each case is treated like a complete study (Yin, 2009). Jointly the cases investigate a phenomenon, population, or a general condition (Stake, 2005). A cross-case analysis then suggests interpretations (Merriam, 2002) and “convergent evidence is sought regarding the facts and conclusions for the case” (Yin, 2009, p. 56).

Case study design can be used to build a tentative hypothesis, and thereby plays an important role in advancing a field's knowledge base (Merriam, 2002). This research is an interpretive case study, which includes elements of categorization, contains thick descriptions, and is “used to illustrate, support, or challenge theoretical assumptions" (Merriam, 2002, p. 38). In this study, these theoretical assumptions relate to the question of gendering practices, and how the interweaving of the disciplines of art and science may disrupt gender stereotypes.

Case studies have been frequently employed in the fields of gender studies and institutional ethnography. Most notable is the groundbreaking work by Yancey Martin (2003) whose research into multinational corporations revealed how gender roles are constructed and enforced within work environments. Yancey Martin examined how men and women socially construct each other at work through gendering practices, which significantly affect both men’s and women’s work experiences. The author described how these gendering practices impair women worker’s identities and confidence and suggested that paying attention to the practicing of gender can produce insights into inequalities at the workplace. Current literature examining the emergent convergence of the fields of art and science also favours the case study format. For example, Miller (2014) demonstrated the intriguing possibilities of art-science research by conducting studio visits and interviews with artists and scientists working at the intersection of art and science, and Edwards (2008) studied innovative practices of institutions such as museums and universities, where the synthesis of art and science helps to develop new educational theories, new forms of art, and avant-garde political policies. These case studies provided compelling insights and proposed new theories.

### 3.3 Definition and Selection of Cases

This study examines two institutions which engage in cutting-edge research: the Exploratorium, an interactive science museum located in San Francisco, California, and the SETI (Search for Extraterrestrial Intelligence) Institute, located in Mountain View, California. The Exploratorium was one of the first museums to structure itself around interactive "hands-on" exhibits, and identifies itself as "a public learning laboratory exploring the world through science, art, and human perception" (About Us, n.d. [website]). Frank Oppenheimer, the Exploratorium's founder, called it "a museum of concepts" (Cole, 2009, p. 166) which emphasizes the act of discovery, play, and lifelong learning. According to the museum's literature, the Exploratorium "has influenced 90% of U.S. science museums and 70% of museums worldwide" (Cole, 2009, p. 302). While the Exploratorium is primarily seen as a science museum, science-informed artworks feature prominently on the museum floor, and the museum employs a complement of artists, engineers, scientists, and educators.

The SETI Institute is a non-profit organization which is dedicated to "explore, understand, and explain the origin and nature of life in the universe" (Our Mission, n.d. [website]). The Institute engages in groundbreaking scientific research in the areas of radio astronomy, signal processing, exoplanet research, and astrobiology. Aside from its scientific research activities, the SETI Institute offers a series of educational outreach programs, such as a NASA-sponsored teacher training program, a collaboration with the Girl Scouts of America, and a library of online teaching resources. In 2010 the SETI Institute launched its Artist-in-Residence program which connects artists with SETI scientists as part of the SETI Institute's outreach program. The Institute hopes that the artists may "bring fresh eyes to help navigate difficult concepts and act as

a bridge to broaden awareness of the science carried out at the SETI Institute" (*SETI AIR,* n.d. [website]).

Both the Exploratorium and the SETI Institute conduct pioneering science research while also engaging in public outreach through education and collaborations with artists. Of the two organizations, the Exploratorium focuses more heavily on interdisciplinary research practices, while collaborations with artists at the SETI Institute constitute only a small component of its outreach program. Contemporary education theories inform the Exploratorium's core mandate, whereas the SETI Institute employs a more traditional educational program. This comparative case study investigates the convergent and divergent aspects of both institutions.

At both organizations I interviewed staff scientists, artists, exhibition designers, educators, curators, and managers to build a picture of the organizations' core philosophies, mandate, and organizational structure. While I conducted a total of 16 interviews of both men and women during the data collection process, for this study I selected the stories of four women who offered especially detailed and comprehensive accounts of their life and work in the fields or art and science. The women are Susan Schwartzenberg and Nicole Catrett, who are employed at the Exploratorium, and Jill Tarter and Margaret Race, who work at the SETI Institute.

Susan Schwartzenberg is the Director and Curator of the Exploratorium's Fisher Bay Observatory, an exhibition space and research centre which is located on the museum's top floor. Susan is a trained artist whose work centres on environmental issues and sustainability. She was a Loeb Fellow for Advanced Environmental Studies at the Harvard Graduate School of Design, and she has worked on several public art projects, most notably the *Discovery Walk* at Stanford University and the *Philosopher's Walk* in San Francisco's McClaren Park. Susan has taught at the

San Francisco Art Institute, the California College of Art, and at Stanford University. She has worked at the Exploratorium for over 30 years, in positions such as staff photographer, designer, artist, and curator.

Nicole Catrett is an artist and exhibit developer working in the Exploratorium's Learning Studio, a research-and-development group whose mandate focuses on hands-on teaching and exhibit development. Nicole studied sculpture at the Rhode Island School of Design and joined the Learning Studio in 2009. At the Exploratorium Nicole collaborates with international artists and educators, and she also maintains an independent artistic practice. In 2011 she received the Exploratorium's Brownlee Innovator award.

Jill Tarter is the former Director of the SETI Institute's Center for SETI Research. She currently holds the Bernard M. Oliver Chair for SETI and serves on the board of the Allen Telescope Array. Jill earned her Ph.D. in radio astronomy at Berkeley University and was one of the first employees of the fledgling SETI Institute when it was still part of NASA. She has dedicated her entire career to the search for extraterrestrial life, and was the inspiration for Carl Sagan's book *Contact*. Jill has earned numerous honours and awards, such as two public service medals from NASA, a Women in Space Science Award from the Adler Planetarium, and the 2009 TED Prize. In 2004 Jill was named one of the 100 most influential people in the world by *Time* magazine.

Margaret Race is an ecologist and planetary protection scientist. She joined the SETI Institute in 1991 to explore possible cross-contamination issues between Earth and other planets that may result from space missions. Margaret's recent work focuses on NASA projects related to Mars exploration, as well as shaping planetary protection policy regarding missions to solar system

planets. Before joining the SETI Institute Margaret worked at the Environmental Protection Agency and at Stanford University's Center for International Security and Cooperation.

The women range in age from their mid-thirties to their mid-seventies, all are North-American Caucasians, and all four earned degrees in secondary education, ranging from a Bachelor to a Ph.D. [1]

All four women are high-profile leaders in their fields and are actively engaged in public outreach, and each woman chose to be identified in this study.

### 3.4 Data Collection

This study was approved by the Concordia University Ethics Committee (certification of ethical acceptability is presented in Appendix A). I obtained written consent prior to each interview. All interviews were conducted in person at the interviewee's place of work, which allowed the participants to guide me through their institutions as part of the interview. The interviews, which varied in length from about 30 minutes to 90 minutes, were recorded using a digital audio recorder. The semi-structured interviews explored the interviewees' educational background, their interest in art and science, any gender-related obstacles they may have encountered, and their current area of research. Interview topics also included the mandate of the institution where the interviewee works, and its link to art, science, and education. The interview questions are listed in Appendix B. After each interview was transcribed, the transcript was sent to the participants for review and approval. I made photo and video recordings of the institutions during and after the interviews. After each interview and site visit, I recorded my impressions and insights in a field journal.

### 3.5 Data Analysis and Synthesis

For the first cycle of coding I applied elemental methods, which are "basic but focused filters for reviewing the corpus" (Saldaña, 2009, p. 66). The initial review was conducted using structural coding, since it is particularly appropriate for studies with multiple participants, semi-structured data-gathering protocols, and interview transcripts (Saldaña, 2009). To foreground the interviewee's personalities I used In Vivo coding, which records "a word or short phrase from the actual language found in the qualitative data record" (Saldaña, 2009, p. 74). In Vivo coding allowed me to capture the nuances of each woman's particular mode of expression. This emphasis on voice is also reflected in the Findings chapter which includes numerous quotes from the interview transcripts. Concurrent with the In Vivo coding I used Process Coding to tag conceptual actions, specifically those relating to problem solving and personal narrative. Throughout the coding process I used analytic memo writing to reflect on the coding process. The analytic memo and the field journal were also coded using structural coding.

During the second coding cycle I employed Axial Coding, which "relates categories to subcategories [and] specifies the properties and dimensions of a category" (Charmaz, 2006, p. 60). The themes and categories which emerged during the first cycle of coding were organized into a visual map using the mind mapping softwares Freemind and Adobe Illustrator. Examples of these maps are presented in Appendix B. The developing structure of the maps revealed a primary narrative which was then connected to the theoretical framework.

### 3.6 Ethical Considerations, Limitations, and Delimitations

While case study design is a popular research methodology, it is often criticized for a lack of rigour, for not following systematic procedures, and for its propensity for biased views (Yin, 2009). Yin suggested that data triangulation may alleviate researcher bias, and that multiple sources of evidence can make the research "hard." For this study, the data gathered from the interviews was triangulated with data collected from field notes, photo and video recordings, as well as information obtained from books and articles about the Exploratorium and the SETI Institute. During data analysis, these additional sources of data helped to validate the information compiled from the interviews. Further criticism regarding case study design was fielded by Merriam (2002), who noted that readers may regard a case study as an account of the whole, and therefore could "oversimplify or exaggerate a situation" (p. 42). Here it is important to note that case studies are not samples, but are "generalizable to theoretical propositions and not to populations or universes." (Yin, 2009, p. 15).

### 3.7 Summary

This comparative case study examined the careers of four women who work at the intersection of art and science, and the conditions and philosophical frameworks of the institutions where they work. The two institutions, the Exploratorium and the SETI Institute, conduct pioneering research in the fields of science, art, and education. The women in this study, Jill Tarter, Margaret Race, Susan Schwartzenberg, and Nicole Catrett, are actively engaged leaders in their fields of research. I conducted semi-structured interviews with the women at their place of work and collected additional data by making photo and video recordings of their work

environments. During the process of analysis I paid close attention to the women's particular modes of expression and personal narrative.

While the accounts of the four women who form the basis of this case study are personal and unique, each story connects to larger issues relating to gendering practices and the art-science intersection. The women's captivating narratives provide nuanced insights into the varying strategies of navigating the limits imposed by gender norms while pursuing their career goals, and reveal how convergent communities of practice in the fields of art and science may help to disrupt restrictive gender roles.

# Chapter 4. Findings

## 4.1 Introduction

As Juarrero and Butler noted earlier, our sense of personhood and gender are not preordained fixtures, but fluid, emergent systems which are continually constructed through recursive, performative acts within a cultural context. This cultural context contains gender norms which limit and restrict women, especially in the male-dominated field of science. Feminist writers and gender theorists suggest that we may disrupt the restrictive gendering practices imposed by society by modulating the culturally prescribed, performative acts by which we construct our identities. This approach focuses on the performative practice of the individual rather than on culturally constructed categories. This chapter examines how, by focusing on practice rather than on categories or labels, institutions can create conditions which allow women to flourish in the sciences.

This chapter is organized into four parts. Part one begins with a short introduction of the four women who are part of this study. This introduction outlines the women's motivations for entering their chosen field of research, and provides an overview of their current work positions. Part two examines the hurdles the women encountered on their career paths, and the strategies they employed to overcome restrictive gendering practices. Part three explores the conditions which foster women who work in the field of science and science-informed art. Specifically, this part examines how institutional practices at the Exploratorium and the SETI Institute help to remove restrictive labels and gender norms by focusing on individual practice and personal expression. Part four investigates the concept of communities of practice. As outlined in chapter two, the identities of scientists and artists are informed by their practice, by shared scripts which

define their roles. These shared scripts create a community of practice, a library of actions and implicit rules and behaviours. This research highlights several convergence points in these communities of practice, areas where shared scripts of artists and scientists overlap to the extend that disciplinary labels become irrelevant. This chapter concludes with a discussion of how these convergence points of communities of practice may create access points for women to enter the field of science.

## 4.2 An Introduction of the Participants of the Case Study

### 4.2.1 Jill Tarter, SETI Institute

Jill grew up in the 1950s as the only child of a father who worked as a fraud investigator at the Securities and Exchange Commission and a mother who was assistant manager at the retail fashion chain Bonwit Teller. Jill was a self-professed tomboy who, in her own words, “acted more like a son than a daughter” (*Jill Tarter — Beating the Odds* (n.d.)). Jill enjoyed spending time outdoors with her father, accompanying him on hunting and fishing trips, and learning how to work with tools.

> My dad taught me how to work with tools and I enjoyed taking things apart and putting them back together. Then I'd have to ask my Dad what to do with the one leftover part. We would walk along the beaches, and he would teach me about the constellations. I loved spending time with my Dad. (*Jill Tarter — Beating the Odds* (n.d.))

At school Jill showed an interest in math and physics, which later lead to a career in the field of science. After earning a Ph.D. in radio astronomy at Berkeley University, Jill was hired by the nascent SETI Institute and has been an integral part of the Institute ever since. When the SETI

Institute was created as an independent non-profit corporation in 1984, Jill was one of its first ten employees (Pierson, n.d., [website]). In 1987 Jill played a key role in putting together a formal Program Plan for SETI, and she was appointed Project Scientist at Ames' SETI office in 1989 (Billingham, 2014, para. 21). Jill currently holds the positions of Bernard M. Oliver Chair for SETI Research and Director, Center for SETI Research. She is part of the SETI Institute's DNA, and enjoys the status of "resident icon" whenever she works at her research station at the Allen Telescope Array in Hat Creek, California, or visits her office in the SETI Institute.

### 4.2.2 Margaret Race, SETI Institute

Margaret grew up in the 1950s and 60s to parents who both worked in the field of science and engineering. During World War II Margaret's mother signed up for the Navy's Women Accepted for Volunteer Emergency Service, or WAVES, and worked as an airplane mechanic. This is where she met Margaret's father who worked for GE jet engines. As Margaret grew up, family outings revolved around science and technology.

> When I grew up we'd go to church on Sunday and we would either go to the airport, to the train yards, or to the Boston Fish Pier and be down by the boats. So, I grew up around technology and dreamt of going places (Personal Communication, July 22, 2016).

Margaret was a strong swimmer and scuba diver, which lead her to develop an interest in marine biology. Her passion for marine environments inspired her to earn a Ph.D. in zoology, and Margaret then worked in the fields of environmental protection and science education. Margaret joined the SETI Institute in 1991 to help shape planetary protection policies which will shield the Earth and other planets from possible cross-contamination as a result of space missions.

### 4.2.3 Susan Schwartzenberg, Exploratorium

While neither one of Susan's parents is an artist, art nevertheless runs in her family. Susan's brother studied music and art, while Susan studied visual art at the Headlands Center for the Arts in California.

> Sometimes I think people don't necessarily know if they're artists or not, they just know they don't want to be in a highly structured environment, they're dreamers, or they like permeable boundaries or something like that. I think both [my brother and I] were sort of like that. Then you find art, which is a different kind of structure, it's one that satisfies that stultifying feeling of the everyday world (Personal Communication, August 9, 2016).

Susan's artistic practice focuses on environmental art with a documentary twist, specifically public artworks that invite visitors to slow down and contemplate the human impact on nature. Susan started working at the Exploratorium in the late 1970s soon after leaving art school and has led a long and varied career at the museum. In 2013 Susan became the Director and Curator of the Exploratorium's Fisher Bay Observatory where she curates the Observatory's exhibits, supervises the artist-in-residence program, and manages collaborations with scientific research institutes.

### 4.2.4 Nicole Catrett, Exploratorium

Nicole has been interested in building, tinkering, and making things since she was a child. "I always really liked building things," Nicole remembers, "when I was a kid I always liked the toys that had motors." Nicole's first visit to the Exploratorium inspired her to study art and sculpture. "I came here when I was five, and it made a really big impression on me ... I went to

the Exploratorium and it was just this wonderland of art and science." Nicole studied sculpture at the Rhode Island School of Design, and a return visit to the Exploratorium as a young adult determined her career goal: a job at the Exploratorium.

> While I was in college I came for a visit to San Francisco and I had totally forgotten about this place, but I came visiting, and I walked through the door, and the first thing I saw was the machine shop. It was in the old space, and you literally walked in the entrance and the machine shop was right there. And I was, like: that's it! That's what I want to do! (Personal Communication, June 1, 2016).

After graduating from art school Nicole occupied a series of jobs which were designed to bring her closer to her goal to work at the Exploratorium. She worked in a toy store, she worked as a welder, and she taught science through the Americorps program, a civil society program which places young adults into community service positions. After interning at the Exploratorium Nicole worked her way up to exhibit developer and finally joined the Exploratorium's Learning Studio in 2009. The Learning Studio is an independent research lab situated on the museum floor where a small group of artists, scientists, and educators develop museum exhibits and workshop projects. Here Nicole integrates her artistic practice with educational outreach through playful, process-oriented experimentation.

All four women are passionate about their work and are active leaders in their respective fields of research. They have worked at the SETI Institute and the Exploratorium respectively for the vast majority of their working lives, and have achieved notable success in their careers. The following section will examine the conditions which made their achievements possible, and the hurdles they had to overcome on their way.

### 4.3 Dealing with Restrictive Gender Norms: Overcoming Hurdles

As outlined in chapter two, gendering practices and their associated power relationships prescribe and enforce behaviours, attitudes, and identity concepts which are not always equitable for women and girls. Authors such as Butler and Haraway suggest that gendering practices can be disrupted by modulating the recursive scripts which prescribe, for example, how to "act like a girl." What strategies may girls and young women employ to subvert gendering practices which restrict their aspirations?

Two approaches for dealing with gender-specific roadblocks are illustrated by the stories of Jill and Margaret. Both had to deal with gender bias which placed hard limits on their activities and career choices. Both overcame their obstacles, but chose different routes: Jill opted for head-on rebellion, while Margaret found alternative paths to outmanoeuvre opposition.

#### 4.3.1 Rebellion

Jill started to collide with the limitations of gender norms in her childhood. As Fausto-Sterling (2005) highlights, children are enculturated along gender norms from birth, and Yancey Martin (2003) remarked that gendering practices are learned and enacted in childhood. In Jill's case, her parents adhered to traditional gender norms typical in 1950s North America: her father was an engineer who went fishing and hunting, while her mother worked in retail and specialized in fashion. Jill was dressed like a girl, but was raised "like a boy," forcing her to navigate the conflicts of living in two worlds. Jill relates how she was torn between two sets of gender norms, and was eventually pressured to abandon one of them.

> My dad, as I was growing up, was the centre of my universe. He had been a professional football player and then became a securities fraud investigator for Wall Street. He actually carried a gun. He was this enormously massive, robust guy, and I was his only child. So, I turned out... I was his son. And I grew up [laughs]… you look at the pictures in our family album, and there will be me in a beautifully ironed and starched dress, and little Mary-Janes and socks, holding a big fish! So, there were these two worlds. My mother had a career in retail, in fashion, she was the assistant manager of a store called Bonwit Teller (Personal Communication, July 8, 2016).

Jill managed to occupy the two, distinct worlds, until, at about eight years old, she ran into a road block. It was Jill's mother who objected to the transgression of gendering practices, and insisted that Jill starts to behave "like a girl." The mother didn't speak to Jill directly, but asked her husband, the authoritative father figure, to enforce the gender rules. The father had a private conversation with Jill: "I've been talking to your mom and she thinks that you should spend less time with me and more time with her learning how to do girl things" (Personal Communication, July 8, 2016). At this moment, Jill could have acquiesced, pleaded, or sulked. Instead, she chose to rebel. "I was just - I went off the handle! I was so incensed. I didn't understand why I had to make a choice, why you couldn't do both" (Personal Communication, July 8, 2016). Interestingly, at eight years old Jill was already well aware of gender norms and knew how to use them to her advantage.

> Of course - you know, women, young girls learn early - early, early, early - how to get your dad on your side, right? You just cry. So, of course, the tears came and we had this conversation, and by the end of it my father said: 'Well, I guess you're right. If you're

> willing to work hard enough, you can do anything you want to do' (Personal Communication, July 8, 2016).

Jill's tears were not those of defeat but of those rebellion. She used them strategically to resist an enforcement of gender norms to which she refused to comply. While Yancey-Martin argued that practising gender is an un-reflexive performance that takes place at a liminal level, practising gender can also be executed deliberately. In Jill's case, the tears of the eight-year-old girl became weaponized, an ordnance which quickly dissolved her father's authority. Note, also, that Jill understood the power relations of her family. By getting her father, the male authority figure, "on her side," she outmanoeuvred her mother and was able to continue to pursue activities that were considered too "male" for her. Jill's act of rebellion went beyond the domestic sphere, but also extended into her future career choice. Jill made another power move, and decided to enter the male-dominated field of science and engineering. In fact, she became a scientist because it was "the most male thing" she could do.

> I said: 'I'm going to be an engineer.' Because my dad had friends who were engineers, and it was the most male thing I could think of. You know, I don't actually think I knew the difference between an engineer who drove a train and engineer who used a slide rule, but - I was going to be an engineer (Personal Communication, July 8, 2016).

While Jill's educational path eventually lead to a successful career in radio astronomy, she encountered a series of obstacles on her way. In high school, some of the subjects available for study were divided along gender norms. Again, Jill ran into the limitations imposed by gendering practices when she found that her interests fell outside the feminine realm. She wanted to take wood shop, because "they had such neat tools" (*Jill Tarter - Beating the Odds*, n.d., [website])

but found that, as a girl, she was not permitted to enroll. Here, Jill employed a dual strategy of acquiescence and rebellion: she completed the home economics course and then insisted on being allowed to take shop class. “After I took home economics, I said ‘Okay, done that, I want to take shop,’ so they couldn't stop me” (Personal Communication, July 8, 2016).

Ironically, when we discussed whether Jill engages in any artistic pursuits, she related that she expresses her artistic side by sewing colourful paisley shirts for her husband, an activity which is traditionally associated with feminine gender norms. When asked whether her interest in sewing may be inspired by her mother’s work in the fashion industry, she paused and then flatly answered, “no.” Not being confined by gendering practices can also mean refusing to be restricted at all, whether the activity is labelled as male or female.

Jill’s strategy of dealing with limiting gender norms is head-on rebellion; through insistence, persuasion, and bargaining. She may compromise and spent *some* time with her mother doing “girl things” or take a home economics class, but having absolved the minimum requirements imposed on her by authority figures, she then changes the script by refusing to perform gender according to the prescribed rules. She is, as Butler would put it, causing “gender trouble” (Butler, 1990).

### 4.3.2 Circumvention

Margaret did not run into gender restrictions in the home during her childhood. Both of her parents worked in the field of science and engineering, and therefore the traditional gender norms did not come into play. While Margaret did not have to contend with gender discrimination at home, she did encounter restrictions early on in her career path. Margaret had a

strong interest in marine biology and made a concerted effort to engage in activities which were associated with this field. “It was everything water,” she noted, be it her studies, her scuba diving lessons, even her competitive swimming. “I grew up near a beach, and so I was a swimmer. And then I became a competitive swimmer when girls didn't do that, especially back in Boston” (Personal Communication, July 22, 2016). By the time Margaret applied at the Boston Aquarium she had the perfect CV.

> I wanted to get a job at an aquarium in Boston that was opening and they were going to be collecting that summer for the tanks. I went there, and I was a biology major from a good school, I am a scuba diver, I live nearby, and they said, ‘we're hiring exactly who you are, but you're a girl’ (Personal Communication, July 22, 2016).

Unlike Jill, Margaret did not rebel head-on. Much like the element of water, which plays such a central part in Margaret’s life, she flowed around the obstacle and found an alternative path which would still allow her to work in her chosen field.

> I ended up getting a job with an agency that did pollution control permits, water pollution control in Massachusetts. And that made me realize that I didn't have to be collecting or touching the animals to be thinking about the environment (Personal Communication, July 22, 2016).

The job Margaret eventually found did not entail such “masculine” activities as scuba diving or working in the field, but was a job considered more suitable for a female: office work. As Yancey-Martin points out, gendered practices place women in a helper position. In Margaret’s case, men occupied the active role of searching and selecting specimen for the aquarium, while women were cast in a supportive role by being relegated to passive desk jobs. However,

Margaret didn't allow herself to become sidetracked. When asked what helped her to persevere, she credited her competitive swimming as a source of inner strength.

> It was a sense of: 'I can do it!' I know I can do it, and that guy was the idiot. But you had to be respectful you couldn't talk up to him. So, I just went and got something else. And I realized that my career has gone like this [makes a wave motion with her hand] (Personal Communication, July 22, 2016).

Note how Margaret did not feel like she could "talk up to him," illustrating Yancey-Martin's observation that women who attempt to alter gender practices are seen as "rocking the boat." Margaret negotiated gender limits through adaptation and circumvention. However, even though hurdles were placed in Margaret's career path, she nevertheless managed to stay focused on her goal: a career in marine biology and environmental science. The code "goal-oriented" was one of the most frequently occurring during the coding process, one that recurred in nearly all transcripts of the women interviewed for this study.

### 4.3.3 Othering

Once women have navigated the obstacles which gendering practices place in their way, they may discover that they are the only females in the crowd. Here the notion of "othering" becomes manifest. As outlined by Butler, Yancey-Martin, and Schiebinger, men are understood as the neutral status quo, while women are always seen as practising gender, as being other than the norm. Feminists associate this othering with an imbalance of power, where the dominant, male group relegates the subordinate, female group to an outsider status. This situation of being the

lone woman in a male-dominated field was experienced by Jill when she entered Cornell University. However, Jill found that her outsider status also offered a positive side-effect:

> At orientation, I was astounded that I was the only woman among a class of 300 engineering students, which was an interesting situation. One benefit was that in the large class sizes, the professors always knew who I was - I was not to be disregarded (*Jill Tarter - Beating the Odds*, n.d., [website]).

Here, Jill decides to focus on a positive aspect of being the "other": increased visibility. Note Jill's choice of words: "I was not to be disregarded." To "regard" is a vision metaphor, from Middle French "regarder," to look, to observe, but it is also an expression of respect, as in "to hold in esteem, to pay attention to." Jill refused to be overlooked, and she refused to be thrust aside. Her resolve to foreground herself correlates with her rebellious approach when faced with limitations, as noted earlier.

Entering her career path one generation later, Nicole also found that being one of the few females can be an advantage because of the increased visibility. Nicole was inspired to work at the Exploratorium after her visit to the museum during her college years, and she realized that she needed certain technical skills to reach her career goal of becoming an exhibit developer at the museum. Acquiring these skills mean that Nicole needed to work in male-dominated domains such as welding and blacksmithing, and even the Exploratorium's shop floor was staffed with a majority of men. However, like Jill, Nicole understands her increased visibility as an advantage.

> I think almost that being female helped me to get in some situations that I wouldn't have otherwise. I kind of stood out. Coming to the Exploratorium, working in the shop, I don't know if I would have been treated differently as a guy, but I think maybe it helped me stand

> out a little bit? Because it is probably a bit competitive. I wouldn't say that's 100% how I got where I am, but … (Personal Communication, June 1, 2016).

Both Jill and Nicole had to deal with being the "other" in their educational and working environment. While Nicole's wording is more tentative, as though she wonders if her visibility afforded her an unfair advantage, both women dealt with the situation by interpreting their outsider status as an asset rather than a liability.

The increased visibility of women working in a male-dominated field can also have an additional benefit: they can serve as role models for other women who are considering entering the field.

### 4.4 Creating conditions that foster women in the sciences

#### 4.4.1 Modification of cultural constructs through role models

"If she can see it, she can be it," a catchphrase coined by the Geena Davis Institute of Gender (https://seejane.org), is often used to encourage more visibility for women and highlight female role models. The Exploratorium has employed female staff in all departments since its inception in 1969, including the exhibit developers who occasionally work on the shop floor. This area is located right at the entrance to the museum floor, "like restaurants that let customers see inside the kitchen" (Cole, 2009, p. 156). Nicole remembered visiting the Exploratorium during a school trip, and noticing women working on the shop floor. This "seeing it" allowed Nicole to imagine herself working there.

> I really got excited about the Exploratorium because there were other women working here and it didn't feel like a closed group. We have this low wall, and you can see people working in the shop. There's quite a few women, and I saw that, and I probably thought that

Figure 1: Exploratorium
The Exploratorium's shop floor is located near the museum's entrance. It is separated from the museum floor by a low partition wall which permits visitors to observe exhibit developers at work.

Figure 2: Exploratorium
A view of the spacious and well equipped shop floor. Both men and women can be seen working there.

> I could be there, too. Because I had a lot of other jobs where there were no women. I was a welder, I also worked as a blacksmith - there were not a lot of women in there! But, by that time I had already had that experience of volunteering in the shop here, and - I don't know, I think seeing other women doing these things gives you an idea that you could do it, too (Personal Communication, June 1, 2016).

Seeing women at work on the shop floor was enough to make Nicole feel welcome. Remember that Jill had to rebel to be allowed to take a shop class in her high school. In contrast, the gendering practice modelled by the women on the Exploratorium's shop floor demonstrated that gender norms were malleable. Nicole understood that she would not need to incite gender trouble if she wanted to work at the Exploratorium as an exhibit developer.

Earlier in Nicole's career the presence of women was also a contributing factor in how she mapped her career path. As noted earlier, Nicole's core interests are building and tinkering, and it is therefore possible that she could have arrived at her present position as exhibit developer via engineering as much as via the arts. However, since Nicole noticed a stronger female presence in the art world, she opted for an art degree.

> I think, also, coming in through the art side instead of engineering - I mean, I could have gone into engineering I guess, but that didn't appeal to me. Coming through the art side, there were more women in that field, but you still learn some of the same skills, you're using the same tools (Personal Communication, June 1, 2016).

Nicole's statement illustrates that the mere presence of women in an educational department can be a deciding factor for a student's career choice. It is also noteworthy that Nicole perceived the traditional gender divide between the male-dominated field of engineering and the female-

dominated field of the arts. The culturally prescribed script of gender boundaries influenced Nicole's educational path, reinforcing recursive gendering practices.

Echoing Margaret's goal-oriented drive to work in the field of marine biology, Nicole was determined to work at the Exploratorium as an exhibition designer. She enrolled for an art degree in sculpture, which allowed her access to the same tools one would find in an engineering department, but in the more acceptable, normative gender context of the arts. This ability to circumvent gender hurdles is reminiscent of Margaret's meandering career path; both women navigated the boundaries of gender norms by plotting sinuous routes which nevertheless lead to the desired destination.

While Nicole benefitted from the presence of role models who dissolved restrictive gender stereotypes, Margaret also benefitted from a role model, though in her case it was a specific person. As a child Margaret Race met astronaut Scott Carpenter, who flew in the Mercury missions in the 1950s. He became a source of inspiration for her and fuelled her passion for science.

> I went to an event in Boston where one of the original astronauts was there, and I went up afterward and met him and have a picture of me as an eighth-grader standing there with Scott Carpenter, and he is the one who got me my scuba lessons. That came through a program later on. I kept in touch with him as a fan-club member for fifty years. They asked me to come to his memorial service as well. I realize that I probably met him eight or nine times in my life, but he touched me. It was that feeling of just 'good job'! (Personal Communication, July 22, 2016).

Even though her physical interactions with Scott Carpenter were minimal, his impact on her was significant: he inspired her and he sustained her self-confidence. Today, Margaret feels that it is her responsibility to be a role model for children, and to encourage them to become engaged with science. She corresponds with school children who write to her at her office at the SETI Institute, and she visits schools both in California and whenever she travels internationally.

Margaret's relationship with Scott Carpenter demonstrates that individuals can become catalysts that shape other people's lives. Such key individuals can also set the tone for an entire institution, such as a school, a museum, or a research organization.

### 4.4.2 Modification of cultural constructs through examples set in the workplace

#### 4.4.2 a) Frank Oppenheimer and the Exploratorium: A Visionary

The Exploratorium is the result of one man's vision. Frank Oppenheimer founded the Exploratorium in 1969 as a hands-on "touch-it museum" (Rosen & Giordano, 1974) where visitors were encouraged to touch and interact with the exhibits. The Exploratorium's byline "A museum for science, art, and human perception" is still in use today, and many of the exhibits on the museum floor date back to the Exploratorium's early days. Oppenheimer had worked together with his brother Robert on the Manhattan Project, and referred to himself jokingly as "the uncle of the atom bomb." After the bombs were released on Hiroshima and Nagasaki, Frank Oppenheimer became disillusioned with institutionalized science, as he saw his work being perverted by the military complex (Cole, 2009). Oppenheimer's disenchantment with institutionalized science correlates with Harding's critique of value-neutral scientific objectivity mentioned earlier, which demands the separation of thinking from feeling and the promotion of

moral detachment. This moral detachment made it possible for Oppenheimer to actively participate in the construction of the atom bomb while betraying his own pacifist principles. However, he acknowledged that he knowingly participated in research that lead to the destruction of thousands of human lives. Oppenheimer recalls hearing the news of the bombing on the radio: “One suddenly got this horror of all the people that had been killed. Up to then I don’t think I’d really thought of all those flattened people” (Cole, 2009, p. 64). This moral tension haunted Oppenheimer for the rest of his life, and many see the Exploratorium as his attempt to repent for his past moral failure (Cole, 2009, Else, 1982).

The Exploratorium is the embodiment of Oppenheimer’s character. As Cole (2009) puts it “Being inside the Exploratorium ... was like being inside Frank’s brain” (p. 143). Oppenheimer passed away in 1985, but his presence is still being felt in the museum. A life-sized cardboard cut-out of Frank Oppenheimer sits on top of a work bench on the shop floor; at once a mascot, an idol, and the Exploratorium’s patron saint. Oppenheimer infected people with a passion for “serious play, and breaking rules; a sometimes obnoxious insistence on transparency, respect for ordinary people, and tolerance for chaos; a taste for big questions and a belief in the power of individuals to effect change” (Cole, 2009, p. 24). Oppenheimer wanted to place science into the hands of the people and saw the Exploratorium as a “scientific public park” (Else, 1982), he felt that a “museum should be a participatory environment where visitors could change what was happening” (Cole, 2009, p. 142). His vision lives on in the museum’s philosophy, or its “genetic DNA,” as Executive Associate Director Rob Semper calls it. Semper, who joined the Exploratorium in 1977 as a scientific researcher and project leader, carries on Oppenheimer’s work, ensuring that the museum’s current activities are coherent with its founder’s core

principles. When asked to define the overall mandate of the Exploratorium, Semper explained: "It's really to help people think for themselves. It's to give them courage, if you want, to be curious, to ask their own questions, to invent suggestions for solutions, and to really think for themselves, to think on their own. That's probably the fundamental thing" (Personal Communication, June 30, 2016).

**4.4.2b) Nicole and the Tinkering Studio: Transparency and Inclusiveness**

The Exploratorium's hands-on philosophy is particularly foregrounded in its Tinkering Studio, "an immersive, active, creative place at the Exploratorium where museum visitors can slow down, become deeply engaged in an investigation of scientific phenomena, and make something —a piece of a collaborative chain reaction—that fully represents their ideas and aesthetic" (*About the Tinkering Studio*, n.d., [website]). The Tinkering Studio is situated on the museum's ground floor and is enclosed on one side by a curved wall with inlaid glass shelves which display toys and project prototypes, much like a cabinet of curiosities. On the other side the space is sectioned off by a mobile fence made of rolls of cardboard mailing tubes, which can easily be moved to respond to the space requirements of each project. The Tinkering Studio's main feature is a modular round table which can be reconfigured depending on the number of visitors present and is continually covered with half-finished projects and tinkering materials. Nicole explains: "[the table] is designed to be modular, it's designed to be social. We spend a lot of time sitting around this table talking or messing around, trying things out" (Personal Communication, June 1, 2016). Under the gentle guidance of Tinkering Studio staffers, visitors are invited to experiment with science, art and technology, mirroring the work of the exhibit


Figure 3: Exploratorium
The Tinkering Studio is situated on the museum's ground floor and is enclosed on one side by a curved wall with inlaid glass shelves which display toys and project prototypes, much like a cabinet of curiosities.

Figure 4: Exploratorium
Visitors and Tinkering Studio staffers experiment with science, art and technology, mirroring the work of the exhibit developers.

developers. Nicole explains, “we have facilitators who help people gain direction, or out of trouble - or into trouble!” (Personal Communication, June 1, 2016). Projects range from open-ended experiments with linkages, to building finished cardboard automata. The Tinkering Studio’s slogan is “Experiments with science, art, technology, and delightful ideas.”

The creative engine behind the Tinkering Studio is the adjacent Learning Studio, an enclosed studio space which is separated from the Tinkering Studio and the museum floor by floor-to-ceiling glass walls. The Learning Studio is the realm of a team of exhibit developers comprised of artists and scientists which Nicole calls “the oddballs of the museum.” The Learning Studio is an independent research and development pod whose mandate focuses on hands-on teaching and learning, and the playful, process-oriented acts of experimentation and discovery. Similar to the Exploratorium’s shop floor, the Learning Studio is also fully visible to museum visitors. The glass walls allow visitors to see the exhibit developers as they build and test their ideas for new exhibits. At the same time, the Learning Studio team is able to observe museum visitors in the Tinkering Studio as they work on their projects. This transparency blurs the boundary between visitor and staff, and between studio space and exhibition floor.

The museum visitors who stop by the Tinkering Studio are an integral part of the process of exhibit design. Ideas for new exhibits are developed by iteration: prototypes are developed in the Learning Studio and are then brought into the Tinkering Studio, where Learning Studio team members observe how museum visitors interact with the prototypes and collect visitor feedback. The project ideas are then brought back to the Learning Studio, where they are further refined. As a result, the visitors contribute directly in the shaping of the museum exhibits. Nicole explains: “We’ll work on something in here [the Learning Studio], and then we’ll take it out and

try it, change it, take it back out. We all work directly with visitors, so, it just goes on forever" (Personal Communication, June 1, 2016).

The Learning Studio's iterative, collaborative exhibit design process parallels the emergent aspects of a complex dynamic system: projects are in a continuous and open-ended flux, and there is a constant flow of information between the visitors and the developers. The Tinkering Studio is an active site of phase change, a permeable boundary between the researchers and the public, and each project iteration becomes a recursive and emergent act. The public's active role in the iterative process also means that a greater diversity of voices contributes to the evolution of the exhibits. Nicole welcomes Tinkering Studio's heterogeneity.

> The best, best, best is when you get a group of people with a mix of ages, mix of genders, mix of races, and that space out there will change dramatically. I've been wanting to take a series of photographs just capturing - okay, so it's a bunch of adults from Thailand, okay, it's a bunch of little boys, okay, it's some grandparents with their grandkids (Personal Communication, June 1, 2016).

The Learning Studio's stance of inclusiveness in the iterative process disperses the boundaries of gender, age, and race. By using the feedback of a large variety of museum visitors as a resource during the discovery phase of project design, the resulting exhibits better serve the diverse populations which visit the Exploratorium.

The notions of inclusion and diversity are also manifest in the Exploratorium's philosophy of blurring the lines between the employees' personal sphere and their work sphere. Frank Oppenheimer wanted the Exploratorium to feel like a home away from home, a place where staff members would want to spend time working on their own projects. "[Frank] wanted people to

feel they could work there forever, that this was their home" (Cole, 2009, p. 268). The flexible boundary between work projects and personal projects is demonstrated by Nicole's creative output, which may begin in her own studio and transition to the Learning Studio, or ideas from the Exploratorium may influence Nicole's personal artworks. For example, her mouse-activated knitting machine is an idea she developed in her own studio, but she has now brought to the Learning Studio to test it as a prospective museum exhibit. As Nicole's pet mice Zelda and Marigold run in their exercise wheel, they turn the crank on a toy-sized knitting machine which creates a long, multi-coloured scarf. Nicole initially got the idea after seeing an exhibit on the museum floor by sculptor Arthur Ganson, who spent a few months at the Exploratorium as Artist-in-Residence. Nicole explains, "This is an example of an idea that got inspired by Arthur's piece, and I got excited about what you could do with a little motion" (Personal Communication, June 1, 2016). Nicole acknowledges that by transferring her personal artworks into the Learning Studio she is introducing ideas which have a gendered spin to them. Her male colleagues may not have invented an exhibit that integrates knitting, an activity that is strongly associated with women. While boys may also show an interest in knitting, Nicole expects that her mouse-activated knitting machine may be especially compelling to girls because needlework and fashion are traditionally female domains.

> I think something like this may be more exciting because it's cute animals, and it's knitting. And also, I think that the exhibits here were all made by different people, and some were men, and some were women, and I think there's a difference. Different aesthetic, different ideas (Personal Communication, June 1, 2016).

The Exploratorium creates working conditions which allow women to realize their own ideas without having to conform to the dominant, male gendering practices that traditionally permeate science-related institutions. Rather than othering women, they are encouraged to integrate their experiences and perspectives into the workplace. At the Exploratorium women are not expected to occupy two worlds.

**4.4.2c) Susan and the Observatory: Self-Realization**

A prime example of integrating personal interests in the workplace is the Exploratorium‘s Fisher Bay Observatory Gallery, which is the brainchild of Susan, the Observatory’s Director and Curator. The Observatory sits on top of the Exploratorium’s bustling museum floor, away from the incessant sounds and lights of the interactive exhibits. The Observatory is a 3,500 square foot, glassed-in structure with an adjacent 2,500 square-foot terrace. Both provide spectacular views of San Francisco’s skyline as well as the Bay and the distant shores of Oakland. Susan notes in her curator’s statement “The Fisher Bay Observatory uses these views as an entry point for investigations of the history and dynamic processes in the local landscape, and the human impact” (Schwartzenberg, n.d., [website]). The Observatory is a quiet space, its exhibits invite observation and reflection. The room is furnished with book shelves and hefty tables that are covered with maps and magnifying glasses. There are several spotting telescopes trained on the Bay, and text-heavy art installations which deal with various environmental aspects of the Bay Area dot both the inside and the outside spaces.

The Observatory is an expression of Susan’s creative vision. Her public artworks invite visitors to contemplate the human impact on nature. Many of her artworks feature “Musing

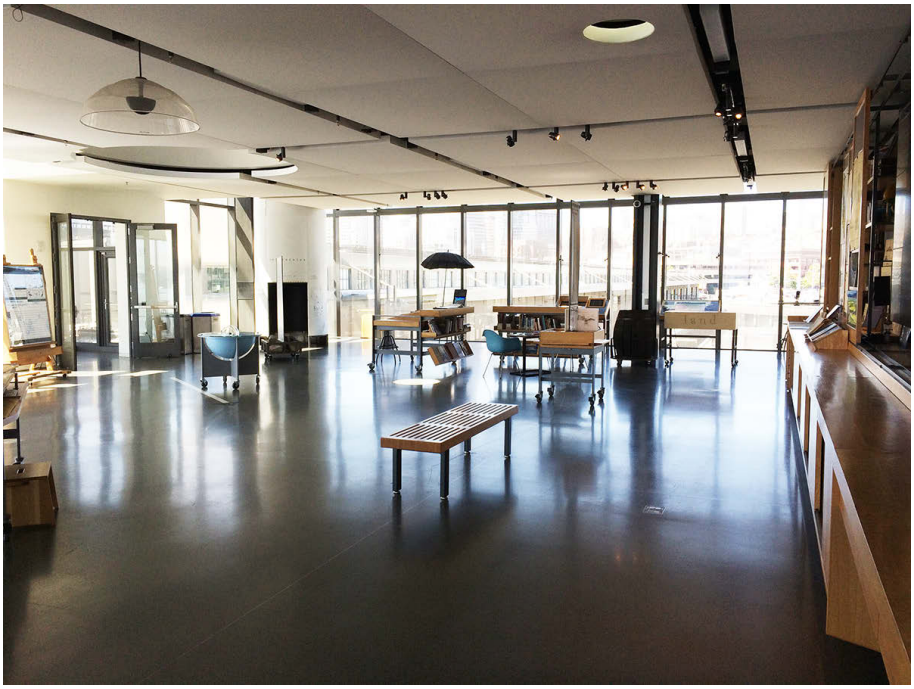


Figure 5: Exploratorium
The quiet, expansive Fisher Bay Observatory is situated on the museum's top floor and provides stunning panoramic views of the city and the Bay.

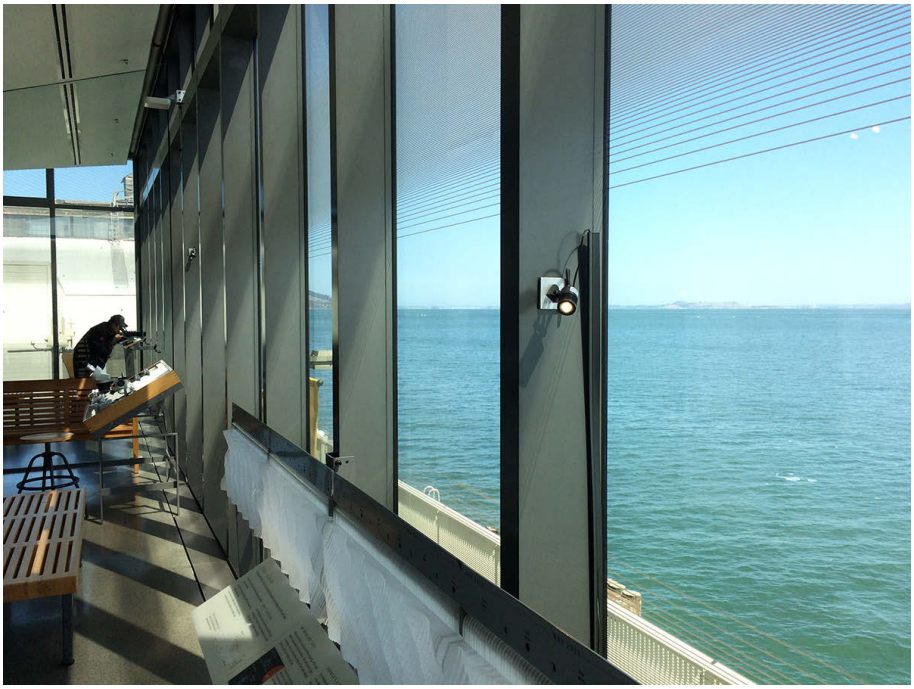


Figure 6: Exploratorium
The Observatory offers several spotting telescopes which are trained on the Bay.

Stations," places which prompt the public to ponder the link between the natural environment and the history of urban development. An example is Susan's recent project "Philosopher's Way" which is installed in San Francisco's John McLaren Park. Susan worked with the Park Service to create a continuous loop of trails around the outside of the park.

> [We] created what we called Musing Stations, which were places to stop people and think about stuff. Sometimes it might be the view, sometimes it might be the history, some story of the local neighbourhood, sometimes it might be noticing how different kinds of plants - there is some restoration there regarding the meadow grasses, reintroducing some historical meadow grasses. So, that was putting narratives out in the landscape, inserting ideas here and there to get people thinking about something other than where their personal reverie might be as they're walking around (Personal Communication, August 9, 2016).

The parallels between the Observatory's mandate and Susan's creative practice are evident: both focus on quiet contemplation, observing and noticing, and on connecting the public with both the urban landscape as well as the natural environment. If the Exploratorium is like walking inside Frank Oppenheimer's brain, then the Observatory is like walking inside Susan's brain. Like many Exploratorium employees, Susan has grown with the museum since its inception. Her career path at the Exploratorium has been upwardly mobile, but serpentine.

> At the Exploratorium I've done everything from being the staff photographer to heading up a media program we started. Then I became more of a curator and involved with exhibition development projects, and when we decided to move the Exploratorium from its old location to Piers 15 and 17 I was given the opportunity to be the curator and now director of the Observatory. ... I feel like my job has been changed every couple of years. Usually

> you are the curator in this, you are the educator of that, and in this museum people meander a bit around (Personal Communication, August 9, 2016).

The Exploratorium's openness to allow its staff to move across departments and job positions is rooted in Frank Oppenheimer's stance toward inclusiveness. "Frank didn't care whether someone had a Nobel Prize or even a GED. He wanted people who could think freely, who had ideas. He believed that if someone was sufficiently enthusiastic about an idea that person would learn how to communicate it" (Cole, 2009, p. 168). Susan's artistic vision carried her through the various departments of the Exploratorium, from an entry-level job as a staff photographer to her current position as Senior Artist and Director of the Observatory. She was not confined by the label "artist" or "woman," instead the focus was placed on her as an individual and her ability to communicate profound ideas about environmental issues.

The Exploratorium's human resources philosophy is built on Frank Oppenheimer's central tenets of inclusion, on the concept of flexible boundaries, and on the value of individualism. It is, ultimately, an egalitarian, humanist agenda which still reflects its founder's vision.

#### 4.4.2d) Jill and The SETI Institute: Open-ended Research

Like the Exploratorium, the SETI Institute was also shaped by the vision of pioneers. The USA's 1958 National Aeronautics and Space Act charged the newly created NASA with "the expansion of human knowledge of phenomena in the atmosphere and space" (Billingham, 2014, para. 4). John Billingham, who directed SETI while it was an in-house branch of NASA in the 1970s and 80s, and later was one of the SETI Institute's trustees, remembers pitching the idea of establishing a SETI program to the NASA Ames Research Center. "One of Ames's roles was to


Figure 7
The SETI Institute, located in Mountain View, is the home of the Carl Sagan Centre.

Figure 8
The SETI Institute's Allen Telescope Array, located in North Hat, California.

be at the cutting-edge of space exploration. I thought NASA and Ames would have the vision and courage to explore the opportunities and perhaps to turn them into an active venture" (Billingham, 2014, para. 4). Billingham was successful, and SETI began to emerge as an entity within NASA Ames in the early 1970s. However, the nascent SETI program at Ames was viewed with suspicion by many mainstream scientists. “Interstellar communication was still generally considered a novelty, a pursuit outside the respectable norms adhered to by most of the scientific community," notes Billingham (2014, para. 11). Specifically within the discipline of radio astronomy, the SETI program was seen as a distraction (Garber, 2014). Compounding the credibility issue was SETI’s perception in the media, something both Garber and Billingham termed “the giggle factor.” SETI "often figured in the media, which sometimes ridiculed our search for mythical ‘Little Green Men’ " (Billingham, 2014, para. 25).

However, the SETI pioneers persevered despite their detractors. It took the combined efforts of scientists from various research centres and universities, such as Caltech, the California Institute of Technology, and the Jet Propulsion Laboratory, to create the SETI division at NASA Ames in the early 1970s. Most notably among them were astronomers Frank Drake and Carl Sagan, and scientist and engineer Bernard (Barney) Oliver. In 1978 Jill Tarter joined SETI as a postdoctoral fellow, and then stayed with SETI for the rest of her career. While the technological aspects of the SETI program were compelling, Jill was “hooked” by the deeper, existential question of SETI.

> It wasn't the technology or signal processing that impressed me - it was that after many millennia of trying to answer the "are we alone?" question by asking priests and

> philosophers what should we believe, humans now had some tools to allow them to do an experiment to try to find the answer (*Jill Tarter - Beating the Odds*, n.d., [website]).

The fact that the SETI program was an unconventional, nascent niche of science provided Jill with an additional bonus. “I was fortunate that gender discrimination didn't play a role as SETI was a fairly new area” (*Jill Tarter - Beating the Odds*, n.d., [website]). While the traditional field of science enacted rigid gendering practices, the fledgling SETI program was nonconformist, and Jill has been an integral part of SETI since joining the program.

Today the SETI Institute is housed in the Carl Sagan Center, located 4.5 kilometres from the NASA Ames Research Center. When the SETI Institute was established most scientists involved with the project at Ames moved to the new Center (Garber, 2014), and some researchers have offices in both institutions. Many SETI Institute employees still frequent NASA Ames for meetings, workshops, and talks. While there is a close relationship between the two institutions, the SETI Institute has its own distinct identity.

The individualist nature of the SETI Institute is noticeable in the visual appearance of the offices and cubicle work stations in the Carl Sagan Center. While they are of the same grey partition wall design found in any typical office, each cubicle and office space reflects the unique character of its occupant. Artworks and artifacts adorn nearly all available wall space. Examples include a quilt which features the planet Saturn as its central motif, several pieces of space-themed stained glass art, a collection of large-format astrophotography prints, and stone sculptures representing the outer planets. The walls of one cubicle are nearly completely covered with silk flowers, another is topped with an array of colourful Chinese paper umbrellas. A life-sized cardboard cut-out of the science fiction character Geordie LaForge from the TV

Figure 9: SETI Institute
A life-sized cardboard cut-out of Geordie La Forge, a character from the science fiction television show Star Trek, towers over the work cubicles at the Carl Sagan Centre. Note the cubicle adorned by colourful paper umbrellas in the foreground.

Figure 10: Exploratorium
A life-sized cardboard cut-out of Exploratorium founder Frank Oppenheimer sits on top of a work bench on the shop floor; at once a mascot, an idol, and the Exploratorium's patron saint.

series Star Trek perches on top of a cubicle wall, a visual echo of the Frank Oppenheimer cardboard cut-out on the Exploratorium's shop floor. Throughout the Center, the shared wall space in the corridors is covered with colourful science posters which illustrate a variety of the SETI Institute's research projects. The Carl Sagan Center feels like a diverse, individualistic space despite its institutional architecture. This stands in stark contrast with its progenitor organization at NASA. A tour of research labs in six different buildings at the Ames Research Center revealed that the individualization of cubicles and work stations at Ames is nearly completely absent. The walls and the work stations themselves are kept in a neutral grey, adorned only with technical charts and framed certificates. Display cabinets showcase items such as prototypes, model fighter airplanes, machine parts, or test results.

The no-frills, conformist work environment at NASA Ames reflects the institute's result-oriented research ethos which is in line with traditional science: projects are undertaken with the purpose of attaining objective and tangible outcomes. While the astrobiology and exoplanet research departments at the SETI Institute may intermittently offer tangible results, outcomes from the SETI research are more fluid. An alien signal could be detected tomorrow, or the sky may be forever silent. Considering the enormity of the task of surveying the entire galaxy for signs of extraterrestrial intelligence, the intervals of SETI research are considerably longer than those of a conventional science project, and possibility of a result remains uncertain. This open-ended structure of SETI research creates openings for qualitative judgments in the formulation of the project hypothesis. Garber (2014) notes that "at bottom, it could be argued that some of what scientists investigate is based on fundamental beliefs, hunches, or with that the world works in some logical way" (para. 41).

Figure 11: SETI Institute
Artworks and artifacts adorn nearly all available wall space. Examples include a quilt which features the planet Saturn as its central motif.


Figure 12: SETI Institute
Throughout the Carl Sagan Center, the shared wall space in the corridors is covered with colourful science posters which illustrate a variety of the SETI Institute's research projects.

This sentiment is shared by Jill, who believes that at the cutting-edge of scientific research, experimentation and knowledge production is more fluid, spontaneous, and unstructured than outwardly acknowledged.

> I think actually there really isn't a scientific method. We sort of bumble along and ask questions, and sometimes when things don't work and when we figure out how to make them work, we make progress. So - scientific method - the world thinks that we do that but we're basically asking questions and try to figure out how… what we can do, what kind of observations, what kind of experiment we can do that will answer those questions (Personal Communication, July 8, 2016).

Note here how Jill foregrounds the researcher. She acknowledges that scientists make choices with regard to the design of experiments, choosing the type of observations to be made, and deciding which questions to ask. Jill's definition of the scientific method is not based on assumptions of value-neutral objectivity, there is no Harawayan "God trick." Instead, Jill draws attention to the person who does the science, she situates the researcher. Jill's approach to science dovetails with Harding's concept of strong objectivity and the notion of (re)embodying the researcher. Jill's choice of the words "we bumble along," implies that there is room for uncertainty, for guesswork, and for inspiration. The notion of uncertainty within the scientific research process was also expressed by Rob Semper, who aside from being the Executive Associate Director at the Exploratorium is also a trained astrophysicist. When he was asked about his thoughts regarding the scientific method he remarked that "we are all incredibly uncertain. We pretend we know, but underneath we're very unsure of ourselves" (Personal Communication, June 30, 2016). This recognition of uncertainty connects to Yang's call to

foreground uncertainty in knowledge production, and to work in a space "where the facts run out." Yang proposed an epistemological shift which abolishes disciplinary distinctions in favour of a polymorphous practice which focuses on skills. This emphasis on skill sets rather than on disciplinary labels creates the possibility for an interdisciplinary practice that transgresses the boundaries of art and science.

As noted earlier, the discipline of science is strongly associated with masculinity. The cultural gender norms which create the dualities man/woman and art/science enforce restrictions which limit women's access to the field of science, as exemplified by the stories of Jill and Margaret at the beginning of this chapter. Dissolving the disciplinary distinctions also dismantles the gendered dualities associated with the disciplines, creating access to the field of science for all.

### 4.5 Convergence Points of Communities of Practice

Are the labels "artist," "scientist," and "engineer" becoming increasingly irrelevant, as proposed by Miller in his book "Colliding Worlds" (2014)? In the Exploratorium's Learning Studio, job descriptions become progressively malleable as team members collaborate on exhibit designs. Nicole explains how working collaboratively with her team members Sebastian, who is a scientist, and Ryan, who is an educator, has led to skill transfers which are eroding their job titles.

> I think, because we've been working together for years now, I think these lines get blurrier and blurrier. Now Ryan knows a lot more about how to build things because I've helped

> him build things, and I know a lot more about physics [from Sebastian] (Personal Communication, June 1, 2016).

Sebastian agrees.

> It's true, with the years it softens up because you're together. Sometimes it feels like you're holding on to a piece of knowledge in the back of your head, but just because someone gave me a degree in Earth Sciences or something, that doesn't define me anymore, after ten years here (Personal Communication, June 1, 2016).

In this collaborative workspace, where an artist, an educator, and a scientist work side by side, labels become fluid, and the community of practice takes centre stage. As noted by Wilson et al. (2015), the parallel cultures of art and science overlap in the area of experimentation and mastery of craft, and practitioners identify themselves more as researchers than as artists or scientists. Wilson et al. (2015) also pointed toward the parallels of the artist studio and science lab as "places of discovery and curiosity" (p. 154). The Learning Studio is a hybrid of both: at once an art studio, a shop floor, and a science lab, it is a place for art and science to mingle, to inform each other, and for labels to be discarded.

Another common denominator exhibited by the Learning Studio team members is a never-ending curiosity about how things work. This curiosity applies to technologies such as automata and drawing machines as well as to natural phenomena. The exploration of linkages, for example, was sparked by the Exploratorium's 2016 summer exhibition *Strandbeest* by Dutch artist Theo Jansen. Jansen's giant wind-animated sculptures resemble roaming dinosaur skeletons, their movements are at once mechanical and eerily lifelike. The sculptures are constructed from ivory-coloured PVC piping, giving the moving appendages the appearance of

bone and cartilage. The *Strandbeest*s' fusion of nature and technology inspired Nicole to explore the workings of linkages in the Tinkering Studio, blurring the line between art, technology, and biology.

### 4.5.1 Nature and Community

The communities of practice of art and science merge at a number of convergence points where attitudes and activities overlap. The most consistent convergence point of the fields of art and science is a deep appreciation for the natural world. For example, while Susan is an artist overseeing an art-science gallery space and Margaret is a planetary protection scientist, they were both inspired by their love for nature.

As outlined earlier, Susan's creative practice as well as her curatorial work in the Observatory centre on the environment. She feels that her personal artistic practice dovetails with the Exploratorium's mandate. "[At] the Exploratorium, all our exhibits are about nature in one way or the other, the fundamental principles of nature" (Personal Communication, August 9, 2016). When Susan was tasked with creating the curatorial mandate for the Observatory, she felt that she had a chance to address what she saw as a gap in the museum's programming when it came to environmental issues:

> There were things about environmental processes, but they were more about the artworks, in a way. ... They are elegant pieces about sand transport and ice formation, wave formation. But we didn't really have a way to study the principles underlying those, and with climate change being so imminent, it felt like an institution like ours should be addressing those things (Personal Communication, August 9, 2016).

As Director and Curator of the Observatory, Susan took the opportunity to implement an environmental outreach mandate that extends beyond the walls of the Exploratorium and connects to the community.

> I feel like I want it to develop a community around environmental issues. I want scientists and policy people and educators to feel this is a place to have events, this is a place to engage the public, and that it be more a centre for environmental studies or something, both about learning and about ways to present it to the public. How do we know what we know about the environment? So I see it being as much about programs and workshops and activities like that as displays of exhibits (Personal Communication, August 9, 2016).

Margaret Race's career also started with a passion for the environment. Remember that Margaret grew up near a beach, that she was an active swimmer and scuba diver, and that she described her area of interest as "everything water." Her love for aquatics sparked her engagement with environmental studies and planetary protection policy.

> I'm a biologist, a marine biologist, and I got into some of these policy issues because I looked at what now I recognize was the impact of emerging technologies on environment. So, I'm an ecologist, and I think about environmental impact. ... I got a call from NASA in the early nineties saying would I come to a workshop, because they recognized that if they went to Mars and they wanted to bring samples back, even if they didn't know if there was life in it, that would be the same kind of public engagement that they would have to take on because of the uncertainty, and that's what started me in this. Honestly, in the beginning I started it because it was an interesting and unusual environmental impact statement

> process, but later on astrobiology really began to blossom (Personal Communication, July 22, 2016).

At the beginning of their career paths both Susan and Margaret had an interest in nature and environmental protection. While Susan went to art school and Margaret studied science, both ended up working in the same research area, an example of how communities of practice can converge on the same focal point. Susan and Margaret's love for nature not only sparked an interest in discovering how the natural world works, but also developed an interest in preserving nature. Both women see themselves as researchers working for a larger common good. Note that both Susan and Margaret engage in outreach efforts that connect their research with the community. Susan made community engagement and environmental advocacy an integral part of the Observatory's mandate, and Margaret volunteers much of her time organizing "Science Café" events in the Bay Area's library network. These events popularize science by contextualizing it with art. The presentations are aimed at an adult audience, and include subjects such as "The Art and Science of Wine," "The Art and Science of Pianos," and "The Science and Technology of Art Conservation." The Science Cafés proved popular, and Margaret eventually prevailed upon the SETI Institute to support her initiative by organizing astronomy-themed Science Cafés and providing resources to present the events to a wider, less affluent audience than those in the area surrounding Berkeley University.

> [In] a place like Mountain View or Menlo Park you have a lot of well-off people. This is Silicon Valley. The same where I was, we were in the shadow of Berkeley. But a little bit further, you get some pretty impoverished areas. In our county we had 23 libraries, and

> once we did it in one library, I could circulate it to other libraries (Personal Communication, July 22, 2016).

For both Susan and Margaret, the common good is a common cause. The communities of practice converge in their efforts to connect their respective areas of research to the human condition, and create a space to acknowledge and reflect on subjective issues and ethical concerns. This work is a counterpoint to Harding's definition of science as a conservative, elitist, masculinist monopoly. Harding faults institutionalized science for its control of resources, and for its use of technical jargon which limits access to science to the general public. However, Susan and Margaret use their positions within their respective institutions to create knowledge-sharing platforms that are accessible to a wide audience. Nor is their work value neutral or promotes moral detachment. Environmental advocacy and planetary protection policy require moral judgments and subjective viewpoints. Both Susan and Margaret acknowledge their cultural agendas and background beliefs without compromising the rigour of their research.

### 4.5.2 Aesthetics and Communication

Another point of convergence of the fields of art and science is the concept of aesthetics. The words "beauty" and "aesthetic" are typically associated with the vocabulary of the arts, but the words also regularly appear in the sciences. Notes Ede (2005) "When I first became interested in science and found myself in the company of scientists, I was regularly struck by their frequent use of a word that is scarcely ever heard in the arts. That word is 'beauty' " (p. 13). In my interviews with both artists and scientists, the word "aesthetic" recurred frequently, however, the term was used in different semantic contexts.

When Nicole develops an exhibit, she focuses first on the aesthetics of the prototype. During a discussion about her experiments with linkages, Nicole explained how she balances aesthetics and functionality.

> I was trying to make something aesthetically, so this is the one I made, it has a sculptural aesthetic that I was going for, but it didn't work at all. Sebastian had some suggestions about how to change the weight, and move this and all of a sudden it acts differently (Personal Communication, June 1, 2016).

The starting point of Nicole's project was its aesthetic component; for her an exhibit needs to "work" on an aesthetic level as well as on a mechanical level. For Nicole, the aesthetic aspect of the prototype is a core function of the project.

For Margaret, aesthetics are a tool to capture someone's attention. She enthusiastically collects and uses infographic posters produced by NASA to get her audience excited about astronomy and environmental studies. She delights in the visual impact of the resource material, as well as in images' ability to effectively transmit information. In the field of astronomy, concepts like distance and time tend to surpass the limits of human understanding. Imagery can help to make these abstract concepts comprehensible, and Margaret relies on her visual aids when she visits schools and libraries. During our interview she showed me one particular poster that she had just picked up at a conference at the NASA Ames Research Center. It was created by a planetary scientist who specializes in lunar volcanism. The poster illustrated how volcanism in the Moon's early history creates a variety of lunar features such as rilles, scarps, and dorsa. The features are hard to distinguish from one another, but the clear visual depictions on the poster helped Margaret to comprehend the cause and effect of the volcanic features.

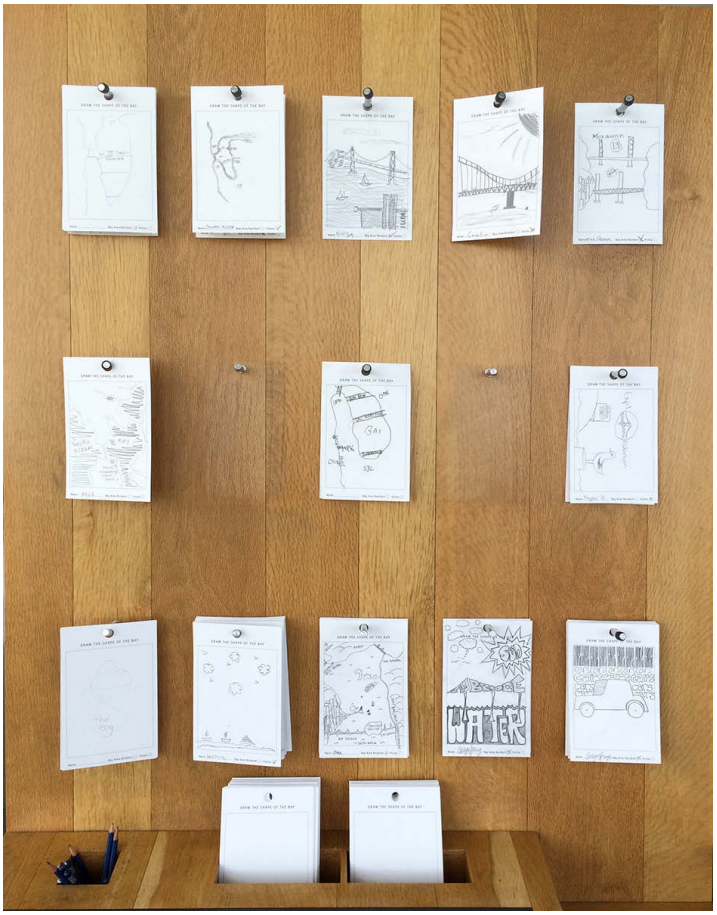
> I'm always collecting stuff. I was over at Ames today, ... NASA is really good about this. Look at the impact! He had one graphic that was incredible, because I was saying 'Wow, I wonder what those things are!' He had it in one graphic. It was incredible! (Personal Communication, July 22, 2016).

What excited Margaret about the imagery was both its inherent beauty as well as its didactic power. Her attitude is encapsulated by Edwards (2009), who defined art as an aesthetic method and a process of thought that is guided by images. Nicole's approach to aesthetics is more intuitive, emerging from play and improvisation. Margaret's attitude toward aesthetics may be more utilitarian than Nicole's, but for both it is an integral component of communicating ideas. Both use aesthetics as a method to help viewers to observe and to think.

### 4.5.3 Drawing and Observing

Observing and noticing are basic skills for both artists and scientists, and form another convergence point between the fields of art and science. Observing activities are often paired with drawing exercises, which are designed to help manifest thoughts in visual form. The act of drawing requires paying close attention to the world, and also provides a tangible representation of inner thoughts. As such, drawing is a way of thinking.

The Observatory offers exhibits which incorporate drawing and observing. Situated next to the Observatory's expansive panorama window, the exhibit titled *Draw the Shape of the Bay* invites visitors to pick up a postcard-sized piece of drawing paper and a pencil, and to create a drawing of the San Francisco Bay. This drawing exercise is not a request to produce a perfectly rendered vista of the Bay, rather it is designed to help visitors think about how their life



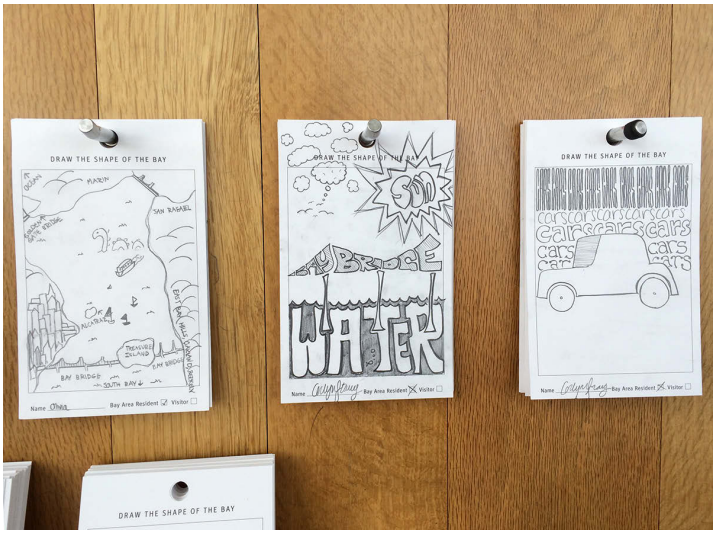



Figure 13 (top) and figure 14 (bottom): Exploratorium
The *Draw the Shape of the Bay* exhibit in the Fisher Bay Observatory.

experiences shape their understanding of the Bay. The creative prompt on the exhibit's panel reads:

> How do you know the Bay? Most of us have probably seen a map of the Bay Area, but we all have different memories and mental images of this place. Your ideas about the Bay, and its shape, are influenced by where you're from, and by your experiences, including time spent reading maps or looking at the Bay from airplanes.

The drawing exercise transforms drawing into visual thinking and helps to express thoughts and ideas. Once the drawings are complete, the hole-punched drawing papers can be displayed on the pegs of a polished hardwood panel. The drawings that are displayed are typically well drawn, suggesting that the Observatory staff curates the visitor's creative output. The display of the visitors' drawings provides an overview of shared impressions and creates a community of vision. The nature of the exhibit echoes the Exploratorium's ethos of allowing the public to participate in the creation of the exhibits. The *Draw the Bay* exhibit is also reminiscent of Susan's public artwork *Philosopher's Way,* each drawing a tiny musing station where visitors may slow down and engage in reflexive practice.

Susan noticed that the exhibits which include drawing activities are especially popular with girls.

> We have a few things where you can draw. You draw the Bay, and then we have another one where one of our Explainers does a drawing workshop sometimes, that's popular with a lot of young people, but particularly young girls. Observation and drawing (Personal Communication, August 9, 2016).

Margaret also uses drawing, both to help her to better observe the world, and as a teaching tool to reveal prejudices. When Margaret visits schools she uses two drawing exercises that help to expose students' preconceived ideas about science. One she calls "Draw a Scientist," the other is "Draw an Alien." In both cases the drawings expose cookie-cutter stereotypes: the scientist is typically portrayed as a man in a white lab coat with "Einstein" hair, the alien is depicted as a green humanoid with huge eyes and antennas. After Margaret presents her lecture, she asks the students to repeat the drawing exercise, and now the drawings are becoming more varied and complex. The scientist may now be a woman, wear ordinary clothes, and be in a natural setting such as a landscape; the alien may be a microbe or a plant.

Margaret uses drawing as a method to externalize thought, and by making it visible it can become a point of discussion. In the classroom setting, the drawing exercise can be used to measure learning outcomes, especially when employing this before-and-after strategy. Margaret also appreciated the act of drawing as a way to help her "see." Margaret remembers taking drawing classes in college.

> A studio art class with the architecture department. It was fascinating - I loved it! The professor said: "I don't teach you to draw, I teach you to see." Isn't that good? He wouldn't correct anything, but ask "Is that really what you see?" (Personal Communication, July 22, 2016).

This is a more subtle way of revealing biases. Inexperienced drawers make inaccurate representations in their drawings because they draw a schema of what they think they see and do not draw what they actually see. In this instance the act of drawing can help scientists as much as artists to observe and to notice, and to correct for inaccurate assumptions. The adage "the eye

only sees what it knows" can be equally applied to the geology of the Bay Area and a life drawing.

### 4.5.4 Questioning and Interdisciplinarity

The most fundamental overlap between the fields of art and science is the act of asking questions. Jill touched on the point of formulating questions earlier, when she described scientific inquiry: "we're basically asking questions, and try to figure out how... what we can do, what kind of observations, what kind of experiments we can do that will answer those questions." Jill sees the opportunity of defining your own questions as empowering, an expression of agency.

> Science is creative - you've got to figure out your own problems and how to solve them - I think there is a lot of authority in that. You're not just punching a clock and do what somebody else tells you to do. You get to work on it and figure it out yourself (Personal Communication, July 8, 2016).

This notion of self-determination and personal freedom is something that Jill also associates with an artist's creative practice. When I asked Jill why she supports the SETI Institute's Artist-in-Residence program, she answered:

> Come on - it's creative! And what we do is not mainstream, the SETI search, nobody's really done a whole lot of it before, so there are no rules, we have to figure out how we're going to do what we're going to do, and art has no rules either. You make your own medium and canvas, and you do what pleases you, and so that's what we're doing here (Personal Communication, July 8, 2016).

Jill is also interested in what kinds of questions the artists in residence may ask the SETI researchers. She feels that by posing unconventional questions, artists can bring a fresh perspective and help the SETI scientists see their own work from a different angle.

> The artists can help us see the work that we do in a different light, ask questions like "why don't you do this?" - that can actually make a difference, and shine a light into corners that we normally don't illuminate and maybe give us some new ideas (Personal Communication, July 8, 2016).

Edwards (2009) asserts that collaborations between artists and scientists reveal hidden assumptions that may limit their work. The convergence of art and science at the SETI Institute's Artist-in-Residence program creates an opportunity for an interdisciplinary research practice that is grounded in the kind of meaningful questioning that was proposed earlier by Yang.

Interdisciplinary research also takes place at the Exploratorium's Observatory. Behind the scenes, the Observatory works on long-term scientific studies with institutional partners such as the National Oceanic and Atmospheric Administration (NOAA), and runs an artist-in-residence program as well as a scholar-in-residence program which generate projects that fuse art, science, and environmental studies. Ultimately, Susan wants to develop a community around environmental issues by creating a space where scientists, policy makers, teachers, artists, and local residents come together to learn about how to preserve the environment. Susan's vision for the Observatory is to develop it into "a place to engage the public, and that it be more a centre for environmental studies or something, both about learning and about ways to present it to the public" (Personal Communication, August 9, 2016). The central question of this interdisciplinary research would be "How do we know what we know?"

To illustrate her point, Susan took me to see one of her favourite new exhibits at the Observatory, created by a recent artist-in-residence, the Canadian artist and landscape architect Jane Wolff. The exhibit *Bay Lexicon* consists of 48 flash cards with simple line-drawing illustrations and questions about San Francisco's boundary with the Bay which is visible from the Observatory. The exhibit's panel states that "Every card is an invitation to look closely at the landscape and to wonder about its meanings," and defines the Bay's edges as "complicated products of the back-and-forth interactions among geographic circumstances, human intention, and environmental processes." The questions on the cards are designed to spark discussion. For example, a drawing of a person on a boardwalk holding a fishing line is accompanied by the question, "How is fishing connected to mining?" and a drawing of the coastline near the Islais Creek is titled "Where does Islais Creek begin?" and then offers the choices, "a. channel, b. drawbridge, c. viaduct, d. headwaters." The cards do not provide any answers, and it could be argued that there is no correct answer to any of the questions. It is the conversation itself that is the purpose of each card. Susan appreciates how Wolff's exhibit uses art as a means to encourage visitors to think about environmental science. Susan explains that Wolff has put her "intelligence to use around scientific concepts, ecological concepts, but still in an artful way. It delivers the message a little bit differently, and I love that" (Personal Communication, August 9, 2016). For Susan, this interdisciplinary type of research erases the art-science boundary. "It's almost like it's not quite art or science, and I find that young practitioners or old practitioners, people that work that way now are some of the most interesting artists around" (Personal Communication, August 9, 2016). The categories "artist" and "scientist" have become irrelevant, it is the act of questioning that is the defining character of Wolff's project.

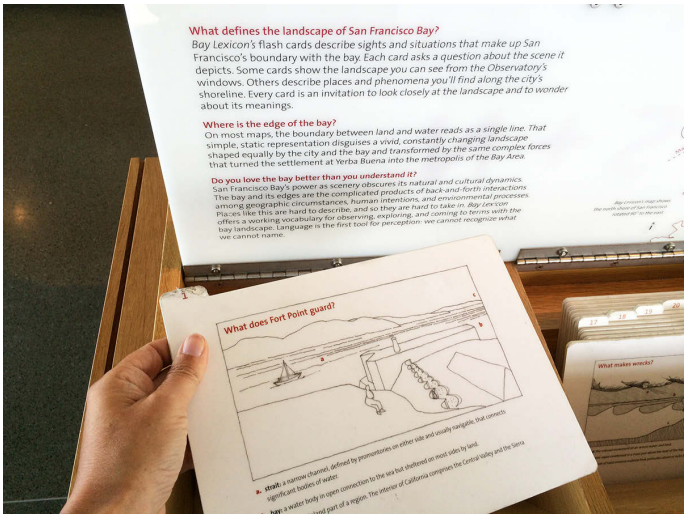




Figure 15 (top) and figure 16 (bottom): Exploratorium
The *Bay Lexicon* exhibit in the Fisher Bay Observatory.

### 4.6 Conclusion

The convergence points of the communities of practice of art and science illustrate that their methods of inquiry are not disparate, immutable categories, but that they overlap and share similar starting points and aims. Fundamentally, artists and scientists perform research and "labels have become irrelevant," as proposed by Miller.

The traditional epistemology that maintains an art-science divide mirrors the concept of Platonic Ideals: there is the Ideal Artist, there is the Ideal Scientist, and any change in their scripted practice is a development toward corruption. However, if we follow Juarrero's definition of identity as an active boundary, the line between artist and scientist becomes permeable. A focus on boundaries as active sites of identity creation means that both artists and scientists are inextricably linked to their context, be it their home or work environment, or via their research activity. Artists and scientists are shaped by the acts of questioning, curiosity, experimentation, and iteration, and by pressures exerted by the social and political environment. If, as Butler states, we become subjects from our performances, the act of performing research liberates us from the recursive scripts that delineate the categories of what it is to be an artist or a scientist. By focusing on the convergence points of the communities of practice we can remove limits and permeate boundaries. These convergence points remove disciplinary distinctions, and by doing so also dissolve the gendered dualities associated with each discipline. This neutral ground creates access points for women to enter the field of science.

The four women in this study rejected the restrictive gendered norms associated with the category "woman" and modulated the script of practicing gender. They negotiated the restrictions imposed by gendering practices through rebellion by refusing to practice gender, or through

circumvention by plotting alternative routes. The women experienced support early in their careers by exposure to role models, who inspired them to pursue their interest in science. Later on in their careers it was the institutional philosophy of their work environment which created conditions that allowed them to flourish. As described in part three of this chapter, both the SETI Institute and the Exploratorium foster individuality by disregarding disciplinary labels and gender categories, instead focusing on the practice of research. By using this approach institutional practices can create space for interdisciplinary research and promote individualism and personal expression. The women were not seen as belonging to the category "woman," "artist," or "scientist," but were identified as researchers, creating an access point to all fields of research.

Abandoning the labels "artist" and "scientist" and focusing on the practice of research dismantles the hierarchy of knowledge which traditionally places objective, scientific knowledge, ahead of subjective, artistic knowledge. Promoting personal expression foregrounds the subjective point of view of the researcher and permeates the line between qualitative and qualitative work. Creating space for individuality communicates that it is not required to conform to a normative standard, that everyone is valued and that nobody is "othered."

As noted earlier by Butler, Fausto-Sterling, and Yancey-Martin, identity and gender are socially constructed through signifying practices which recursively construct both the individual and the social environment in a continual loop. The social environment is mediated by power relations, which are expressed through gendering practices which equate men with "dominant, normal," and women with "subordinate, other." This creates an unequal power structure which imposes restrictive gender norms for women, norms which are especially pronounced in the

male-dominated field of science. Feminists such as Haraway propose that the man/woman duality can be collapsed by modulating gendering practices. This research proposes that this focus on signifying practices can also collapse the duality art/science. An examination of the communities of practice in the fields of art and science revealed convergence points where artistic and scientific research overlap. These convergence points can act as access points for women to the field of science. Since science is typically associated with masculinity and art with femininity, this approach has the potential to equalize the gender balances which is linked to knowledge production.

# Chapter 5. Conclusion

## 5.1 Summary

This research examined the conditions in which women and girls enter the field of science, and how the integration of art and science can offer new opportunities for women and girls who encounter hurdles in the STEM field due to restrictive gendering practices. To this end this case study examined the experiences of four women who work in the fields of science and science-informed art: Jill Tarter and Margaret Race from the SETI Institute, and Susan Schwartzenberg and Nicole Catrett from the Exploratorium.

The women in this study were interviewed about how their interest in science developed in childhood and adolescence, their educational backgrounds, and their chosen career paths. This research employed the theoretical frameworks of complexity theory and gender theory to analyze the women's personal experiences, and then applied feminist standpoint theory and institutional ethnography to position these experiences within the conditions of the women's work environment.

The four women related their encounters with restrictive gender norms in the field of science, and shared the strategies they employed to negotiate the gender-specific impediments they encountered on their career path. These strategies were either head-on rebellion against gender norms through the refusal to practice gender, or the circumvention of gender restrictions by finding alternative paths to reach the chosen career goal. The motivating factors which kept the women from capitulating in the face of opposition were their own goal-oriented determination, and the role models which directly or indirectly inspired the women during childhood and adolescence.

Once the women entered the work force at the SETI Institute and the Exploratorium, they found that the company philosophies and working conditions of these institutions played a positive role in their career development. This research identified several commonalities in the philosophical frameworks of both institutions which created these favourable conditions: a disregard for disciplinary labels, a strong focus on the act of research, a support of individuality, and a non-conformist attitude. Of special interest is both institution's emphasis on individual research practice over disciplinary labels and gender categories. By focusing on the practice of research, labels such as "artist," "scientist," "man," and "woman" become irrelevant, and are replaced by the term "researcher." The shared scripts of performing research create a community of practice, a library of actions and implicit rules and behaviours.

An examination of the communities of practice of the women in this study revealed four major convergence points in the research practices of the fields of art and science:

a) Nature and Community

A deep appreciation for the natural world ignited the women's interest in science, which in two cases (Margaret and Susan) developed into a concern for environmental protection and community outreach.

b) Aesthetics and Communication

For Nicole, the creative process balances functionality and aesthetics. Both core elements need to be present for her to deem a project to be successful. For Margaret, aesthetics is seen as a tool to capture someone's attention, and as a visual aid when scientific information reaches the limits of intellectual understanding.

c) Drawing and Observing

Both Susan and Margaret see drawing as a tool to help people to see, to notice, and to slow down and think. Both women also use drawing as a tool to make visible modes of thinking, revealing hidden preconceptions and biases.

d) Questioning and Interdisciplinarity

For Jill and Susan, the act of questioning defines both the artist and the scientist. Jill sees the act of questioning as an empowering expression of agency which cuts across disciplines, while for Susan the central question of interdisciplinary research is "How do we know what we know?"

The convergence points of the communities of practice of art and science share similar starting points and aims, making disciplinary distinctions inconsequential. By removing disciplinary categories, the convergence points also remove the gendered dualities associated with each discipline. Since science is associated with masculinity, dismantling the disciplinary duality of art/science, also dismantles duality of man/woman, creating an access point for women into the field of science.

### 5.2. Implications and Recommendations

By focusing on the convergence points of communities of practice, educational institutions can create conditions which foster women who are interested in pursuing a career in the STEM field.

This research proposes that educational institutions can create these favourable conditions by adopting an ontological stance which understands categories and labels as limits, and

individual research practices as boundaries. Defining “artist,” “scientist,” “woman,” and “man” as a label creates a limit, described earlier by Cilliers (2002) as something that can only be known from one side and where “we cannot know what is beyond it” (p. 82). In other words, someone is a scientist up to a certain point, and if this limit is crossed the identity of “scientist” is forfeit. Here labels create limiting restrictions which are culturally constructed from the outside through societal power relations. Defining “artist,” “scientist,” “woman,” and “man” through their individual practice creates a boundary. Juarrero (2002) portrays boundaries as active sites of phase change where existential decisions are made between individuals and their environment. In this case, it is the individuals who create their identities through choices made, one is an embodiment of one's action. If we become subjects from our performances, as posited by Butler (1990), then the power to create our identities rests within us, and is not determined by externally imposed categories. This theoretical framework creates a transdisciplinary space which can help to break down the gender restrictions and gender stereotypes which discourage women and girls from connecting with STEM fields.

The emphasis on research practice over categories could also be applied to the disciplinary structures of educational institutions. In schools, colleges, and universities, disciplines are divided into faculties, and knowledge production within these faculties is strictly categorized. Knowledge bases are further fragmented into subjects creating another layer of limiting classifications. By disregarding categories and focusing on research practice, educational institutions have the opportunity to exploit the convergence points of communities of practice and create a common ground which is accessible to both girls and boys.

The four convergence points of the communities of practice outlined in this study (nature and community, aesthetics and communication, drawing and observing, questioning and interdisciplinarity) can serve as launch pads for cross-curricular education. Research-based study projects can create opportunities for collaborations between faculties, making both art and science more accessible to those who do not self-identify as "scientists" or "artists." This approach may be of special interest to educational researchers working in the field of STEAM education. STEAM education interweaves art with STEM subjects with the aim of advancing innovative practices, particularly in the areas of technology and engineering. By acknowledging the gender bias associated with science, STEAM educators can participate in creating more equitable conditions for women and girls wishing to enter the field of science.

### 5.3 Directions for Future Research

This research identified four convergence points in the communities of practice of the fields of art and science. Further research could investigate how these convergence points can be integrated into cross-curricular educational frameworks in schools, colleges, and universities, and how they could be deployed in the context of museum education, both in art museums and in science museums.

Additional research could explore possible convergence points in work environments where research is performed, such as artist studios, science labs, field stations, and shop floors. What protocols and processes are being followed, which materials and tools are being used, and what are the expected outcomes? How are certain tools and processes associated with gender bias, and how could a focus on research and convergence help eradicate such biases?

In this context, the emergence of Makerspaces may provide a valuable environment for a study of this kind. Makerspaces are independent, collaborative spaces where people meet to work on creative projects through the use of technological experimentation, art, and innovation (Sharples, 2013). These spaces typically provide shop tools, new technologies such as 3D printers and computers, as well as tools and materials typically found in an art studio. How can such an environment help to dismantle gender barriers? Makerspaces are social environments which are driven by collective learning, information sharing, and member interactions, one of the key components in Lave and Wenger's definition of community of practice. Future research could investigate possible convergence points in the social structures of the communities of practice within the domains of art and science, and how these convergence points could dismantle restrictive gendering practices.

These avenues of research could help to reveal unacknowledged gender biases, address the gender gap in STEM fields, and create a more equitable learning environment for both girls and boys. It is my hope that this study will help to develop theories related to the engagement of women and girls with STEM subjects, and create new opportunities for anyone who wishes to engage with science and art.

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## Footnotes

[1] Delimitation: This information is provided to better situate the four participants in their cultural context. However, this work does not explore aspects of relating identity with education or race.

[2] Delimitation: The project *Nature?* (2000) by Marta de Menezes is discussed in the context of co-creation and collaboration between artists and scientists and overlapping interdisciplinary practices. It is not an endorsement nor a critique of the ethics of working with animals in scientific or artistic practice.

## Appendix A. Certificate of Ethical Acceptability


CERTIFICATION OF ETHICAL ACCEPTABILITY
FOR RESEARCH INVOLVING HUMAN SUBJECTS

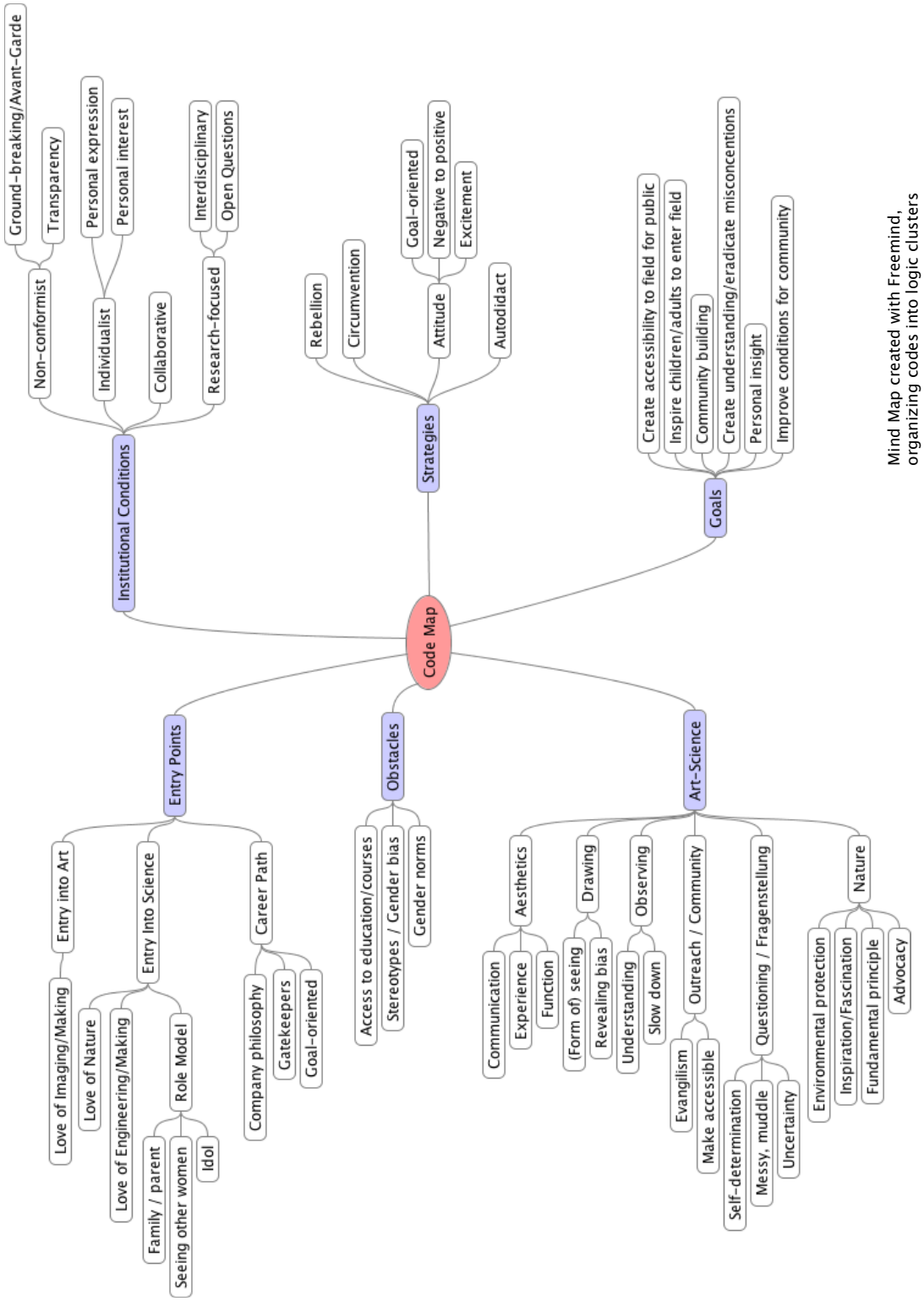
| | |
|---|---|
| Name of Applicant: | Bettina Forget |
| Department: | Faculty of Fine Arts\Art Education |
| Agency: | N/A |
| Title of Project: | Recontextualizing Art and Science: Connecting Women and Girls with STEM Subjects through MakerEducation |
| Certification Number: | 30008173 |

Valid From: August 03, 2017 To: August 02, 2018

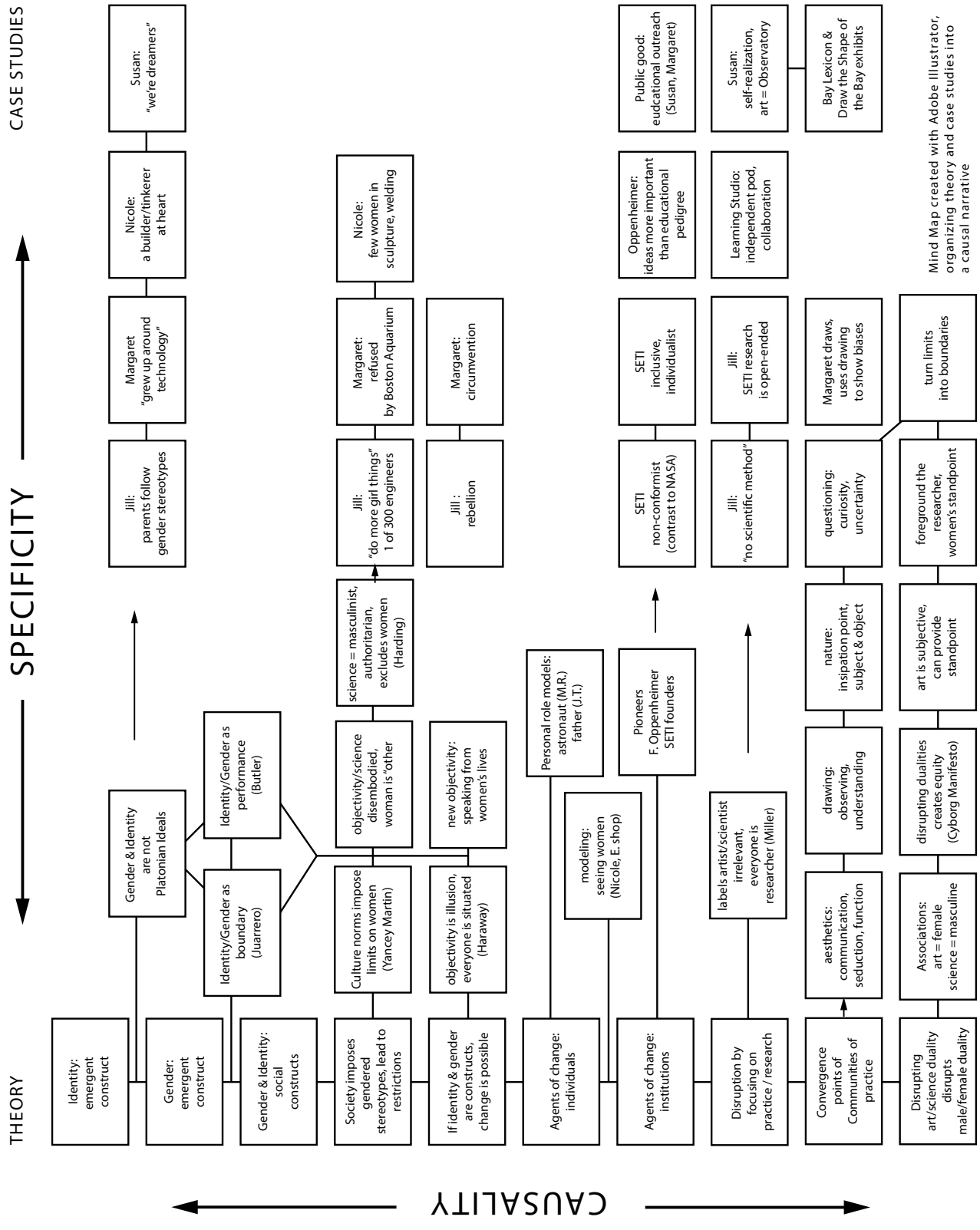
The members of the University Human Research Ethics Committee have examined the application for a grant to support the above-named project, and consider the experimental procedures, as outlined by the applicant, to be acceptable on ethical grounds for research involving human subjects.

Dr. James Pfaus, Chair, University Human Research Ethics Committee

## Appendix B. Mind Map #1



## Appendix B. Mind Map #2



## Appendix B. Interview Questions

### Exploratorium and SETI Institute: General Questions

How did you become interested in science?

What is your educational background?

How did you come to work at the Exploratorium/SETI Institute?

Did you encounter any hurdles on your career path?

Do you engage in any art making activities?

### Exploratorium: Specific Questions

Tell me about the Exploratorium's STEAM education strategies.

Tell me about the Field Explainer Program.

Tell me about collaborations between artists and scientists.

### SETI Institute: Specific Questions

Tell me about the Artist-in-Residence program.

Tell me about your educational outreach program.

What are your thoughts regarding the intersection of art and science?